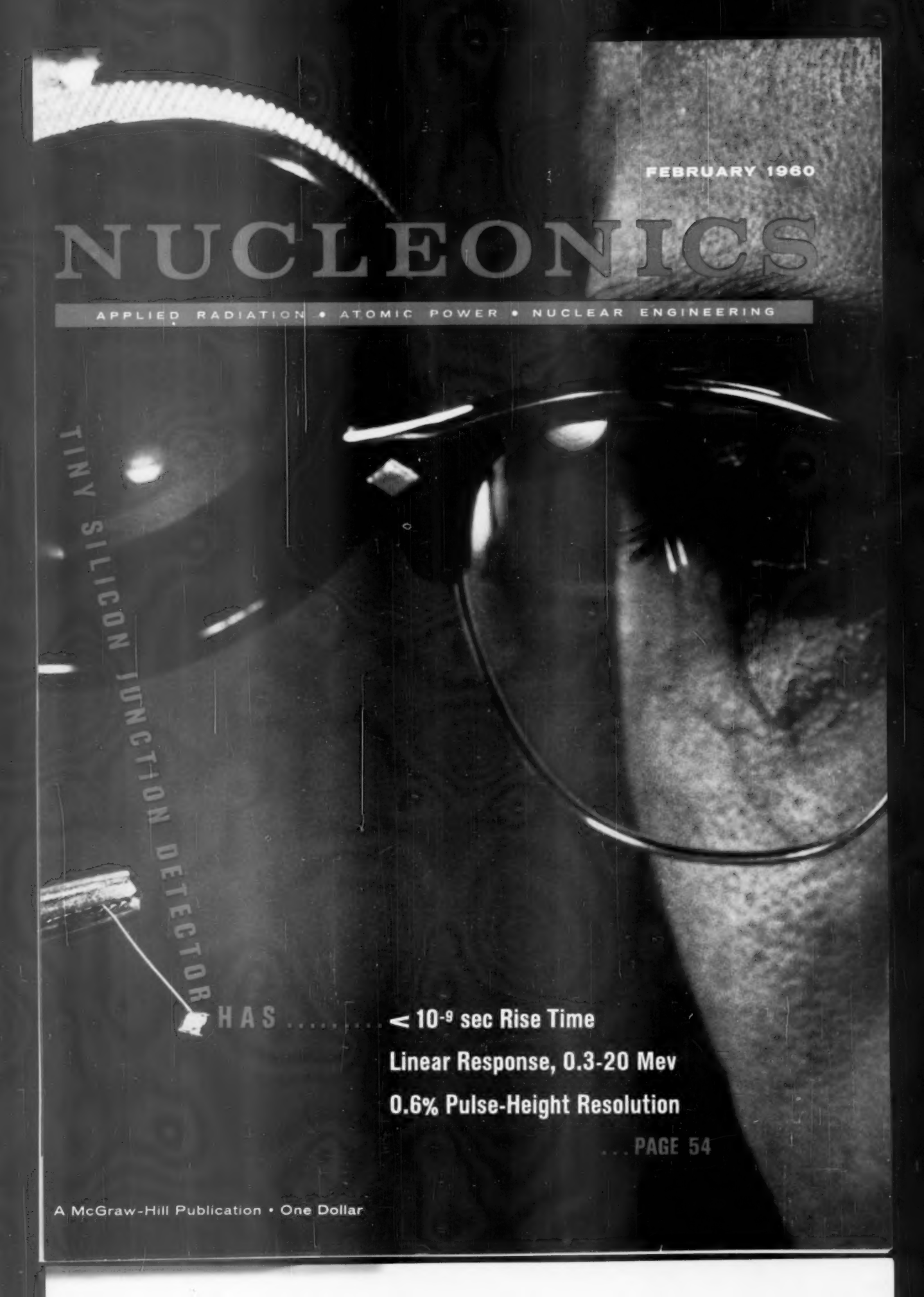


FEBRUARY 1960

NUCLEONICS

APPLIED RADIATION • ATOMIC POWER • NUCLEAR ENGINEERING

TINY SILICON JUNCTION DETECTOR HAS .....

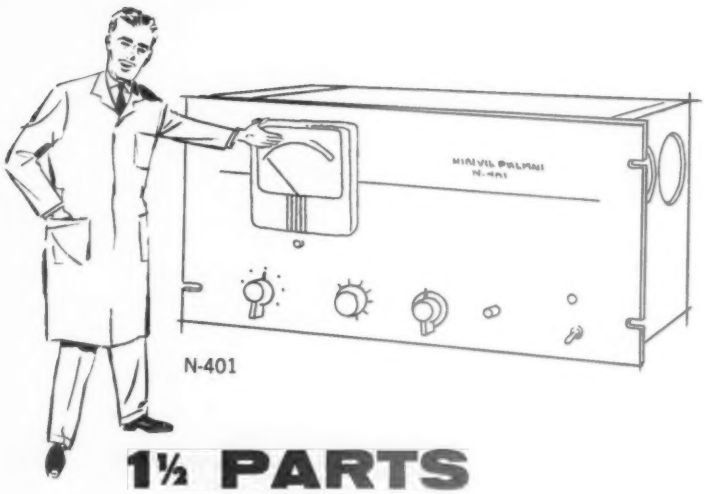
< 10^{-9} sec Rise Time

Linear Response, 0.3-20 Mev

0.6% Pulse-Height Resolution

...PAGE 54

A McGraw-Hill Publication • One Dollar



1½ PARTS PER MILLION LONG TERM STABILITY*

In Hamner's N-401 High Voltage Power Supply, stability is unexcelled, yet its measurement for the purpose of laying down specifications posed a great problem. The measurement was made by a leading university noted for their precision measurements of atomic constants by X-ray methods. The results obtained indicated a basic long term stability of *approximately 1½ parts per million per day — actually more stable than batteries. In the experiment, resistances used to attenuate the N-401's output had been aged and their values studied for over 50 years. Temperature was held constant to within .05°C.

Voltage: 500-1800 V, dual polarity
Current: 0-5 ma
Noise and Ripple: Less than 1 mv rms at full output

The N-401 has been designed for use in scintillation and proportional counting systems, where other systems components offer the same degree of stability.

Some of Hamner's other instruments are described at the right. Each instrument has been designed to operate as an independent unit or in a system with other Hamner instruments.

Send For This Informative, Short-Form Catalog.

Hamner
Electronics Co., Inc.
Dept. 2, P.O. BOX 531, Princeton, N. J.
PEnnington 7-1320

N-303 Amplifier with Single Channel Pulse Height Analyzer and Integral Discriminator

Amplifier

Gain: 10,000 at 2½ mc bandwidth
Gain Stability: .25%/day
Hum and Noise: Less than 2V peak to peak at full gain
Linearity: Better than .1%, 0-100V, into 10K

Analyzer

Resolving Time: 1.3μs
Window Width Stability: 10mv/day, 0-10V width
Base Line Stability: 50mv/day, 0-100V
Linearity of Base Line: Better than .1%, 0-100V

Both analyzer and discriminator may be operated simultaneously to record pulse height distribution and at the same time monitor background noise.

N-270 Scaler for High Speed and Automatic Systems

Resolution: 1 μs for pulse pairs
Preset Count: 10, 10^2, 10^3, 10^4, 10^5, 10^6, 10^7, 10^8
Discriminator: −.25 to −5V or −50 to +100 volts

The N-270 may be used with a digital recorder for data print-out and can be gated on and off, recycled, etc., by the N-801 timer.

N-801 Electronic Timer

Accuracy: .1%
Preset Time: 0.5, 1, 2, 5, 10, 20, 50, 100, 200, 500, or 1000 secs.

Timer will provide signals for gating N-270 scaler.

N-701C Log Count Rate Meter

Range: 1 to 10^5 CPS in 4 scales
Discriminator: −50 to +100V or −.25 to −5 volts
Accuracy: ± 1% of log of count rate

Besides other models of the above mentioned units, Hamner also offers a complete line of GM, proportional and scintillation detectors with suitable preamplifiers for a variety of applications.

FIELD REPRESENTATIVES

RAYTRONICS COMPANY
Massachusetts, New England States

A. B. EDWARDS
Eastern Pennsylvania

BEN Z. RUBIN CO.
Michigan, Indiana, Ohio, Northern Illinois, Wisconsin

W. A. BROWN & ASSOCIATES
Alabama, Delaware, Florida, Georgia, Kentucky, Maryland, North & South Carolina, Tennessee, Virginia, Washington, D. C.

EARL LIPSCOMB ASSOCIATES
Texas, New Mexico, Oklahoma, Arkansas, Louisiana, Mississippi

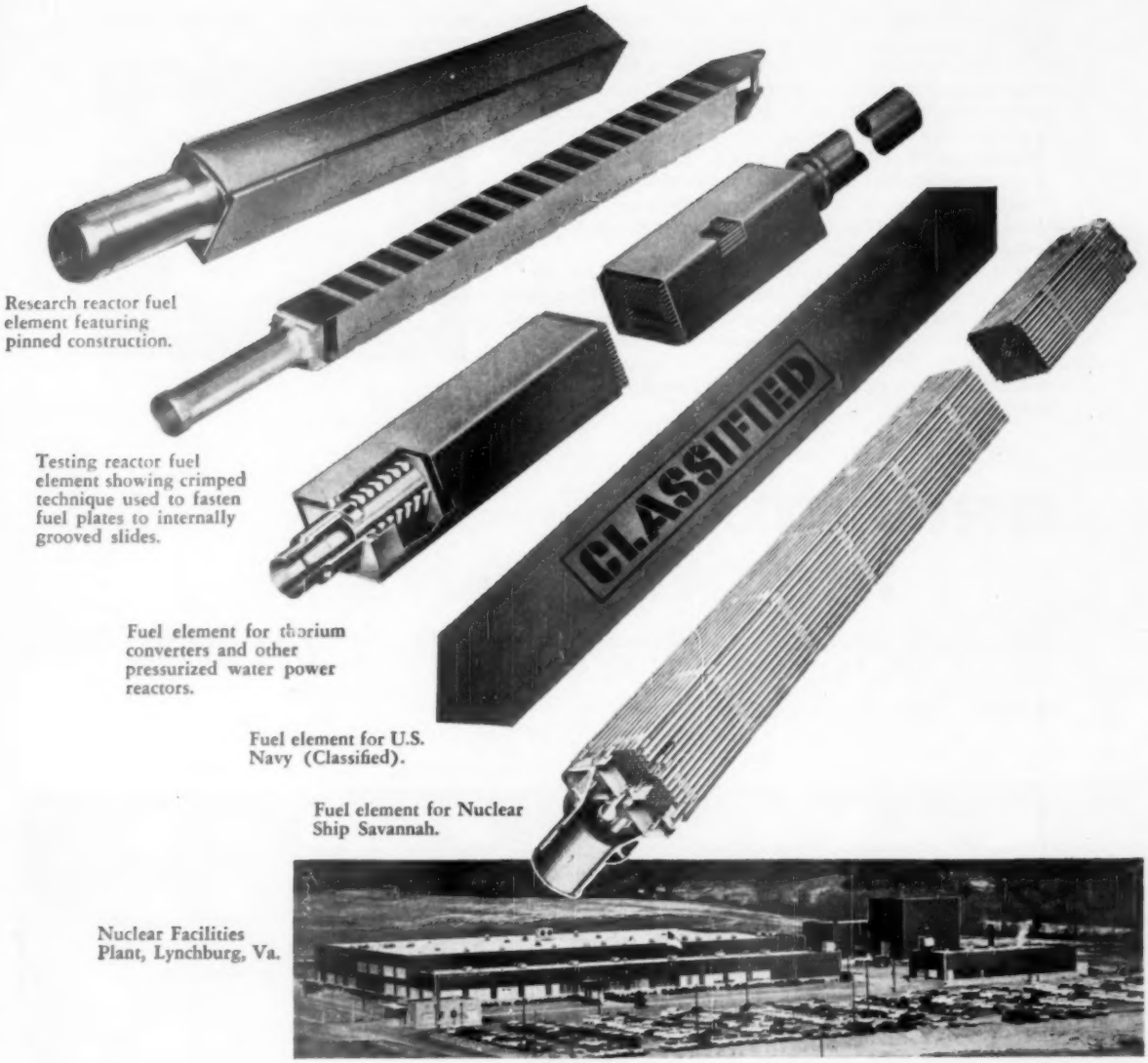
H. E. RANSFORD CO.
Pennsylvania, Northern West Virginia

LANDFEAR ENTERPRISES
Met. New York, New Jersey

R C TESTING & CONTROL SYSTEM
Ontario, Quebec, New Brunswick, Canada

McCARTHY ASSOCIATES
Arizona, California, Nevada

EXPORT DEPT. 202 East 44th St., N. Y. C.
Cable: Henleysale RCA Teletype 210, N. Y. C.



Research reactor fuel element featuring pinned construction.

Testing reactor fuel element showing crimped technique used to fasten fuel plates to internally grooved slides.

Fuel element for thorium converters and other pressurized water power reactors.

Fuel element for U.S. Navy (Classified).

Fuel element for Nuclear Ship Savannah.

Nuclear Facilities Plant, Lynchburg, Va.

What Should a Buyer of Fuel Elements Look For?

Experience—B&W has supplied thousands of fuel elements, and has one of the nation's most experienced staffs of nuclear scientists and technicians.

Special Skills—Whether the fuel elements you require are standard elements, or of radically new design, you will receive the full attention of B&W specialists. You will be sure that you're getting the best fuel elements for your application.

Superior Workmanship—Stringent quality control is a tradition at B&W. Almost a century of custom engineering has taught us that there's no substitute for superior craftsmanship and attention to detail.

Responsibility—B&W will accept your uranium, or will take full responsibility for procuring and processing uranium for you, depending on your needs.

Prove it for yourself—Talk over your fuel element needs with an experienced B&W specialist. Write for more information to The Babcock & Wilcox Company, Barberton, Ohio.

B&W

THE BABCOCK & WILCOX COMPANY

BOILER DIVISION

NC-103

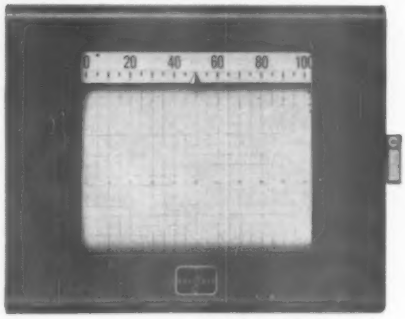
Complete nuclear systems, cores, components, fuel elements, nuclear research and development

World's first mobile, self-contained nuclear power plant and first U. S. gas-cooled reactor for generating power—these are the dual aims of the Gas-Cooled Reactor Experiment Program (GCRE-I), being carried out at the National Reactor Testing Station, Idaho, for the U. S. Army and U. S. Atomic Energy Commission by Aerojet-General Nucleonics.

We're proud that Aerojet-General, prime contractors for the Army Gas-Cooled Reactor Systems Program and builders of both the reactor and its control system, selected Bristol Dynamaster* potentiometer and bridge instruments to record vital reactor data.

Bristol offers control-systems builders—whether for the nuclear or any other industry—the widest instrument choice on the market for measurement, recording, automatic control, and telemetering. Electronic and pneumatic types. Full-size and miniature (3" strip chart) types. For complete data, write: The Bristol Company, 147 Bristol Road, Waterbury 20, Conn. 9.25

Bristol Dynamaster* Electronic Potentiometer or Bridge Instrument, strip-chart model.



*T. M. Reg. U. S. Pat. Off.

BRISTOL INSTRUMENTS *record Army reactor's progress*

Control Room for GCRE-I Gas-Cooled Reactor Experiment. Bristol Dynamaster instruments are at top of "stand-up" panel at rear. Photo courtesy of Aerojet-General Nucleonics, San Ramon, Calif.

BRISTOL... for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

NUCLEONICS

APPLIED RADIATION • ATOMIC POWER • NUCLEAR ENGINEERING

FEBRUARY 1960

VOLUME 18 NUMBER 2

FEATURE ARTICLES

54 Tiny Semiconductor is Fast Linear Detector
STEPHEN S. FRIEDLAND, JAMES W. MAYER and JOHN S. WIGGINS

60 Breeding—How Soon A Necessity?
W. K. ERGEN and E. L. ZEBROSKI

67 Radiation-Resistant Fluids and Lubricants
WILLIAM L. R. RICE, DAVID A. KIRK and WILLIAM B. CHENEY, Jr.

72 How AEC Plans to Process Power Reactor Fuels
C. E. STEVENSON

74 Irradiated Males Eliminate Screwworm Flies
MERRILL E. JEFFERSON

INSTRUMENTATION & MEASUREMENTS

78 Detection of Irradiation Effects by Differential Thermal Analysis
C. B. MURPHY and J. A. HILL

82 Transistorized Voice Amplifier for Use with Respiratory Masks
J. R. GASKILL and O. L. MEADORS

85 Semiconductor Fission Probe
ROBERT STEINBERG

NUCLEAR ENGINEERING

86 Physics of Breeding Reviewed

86 Neutron Source for Argonne Fast-Reactor Studies

88 Slide Rule Simplifies Xenon Computations
DAVID E. DICKEY and JOHN E. McEWEN, Jr.

96 Hot Reloading of In-Pile Tests
H. K. RUHL

APPLIED RADIATION

98 Russian Gamma Sources
R. HOBART ELLIS, Jr.

100 Britons Open Pilot Plant to Try Radiation Processes
JOHN TUNSTALL

105 Radiation Seeks Commercial Use
S. EDWARD EATON

DEPARTMENTS

NUCLEAR REACTIONS 6
ROUNDUP 17
EDITORIAL 53
APPLIED RADIATION 98
BOOKS 108
PRODUCTS AND MATERIALS 112
INDUSTRY NOTES 122
NUCLEAR CALENDAR 123
NUCLEAR CAMPUS 124
NEWSMAKERS 125

COMING FEATURES

NEXT MONTH
Radiation Improves Wood
Chemical Radiation Protection
Waste-Disposal at Shippingport
Nuclear Congress Show Report

LATER MONTHS
Tomorrow's PWR's
Scintillation Counting Symposium
Uranium Monocarbide
Radiation Chemistry of Hydrocarbons

Official U.S. Naval Observatory Photo

Jerome D. Luntz, Editor and Publisher

Daniel I. Cooper, Managing Editor

Thomas L. Cramer, Associate Editor
John E. Kenton, News Editor
R. Hobart Ellis, Jr., Associate Editor
Harold L. Davis, Associate Editor
Robert E. L. Adamson, Assistant Editor
Carol Williamson, Production Editor
Tom Howland, Jr., Art Director

John Wilhelm, Manager, News Bureaus
Washington—G. B. Bryant, Jr., Chief; Ernest Conine, Richard A. Smith
London—John Shinn, John Tunstall
Paris—Robert E. Farrell, Arthur L. Erikson
Bonn—Morrie Helitzer, Silke Brueckler
Moscow—Robert Gibson
Tokyo—Sol Sanders
Rio de Janeiro—Jerry Gingell
Mexico City—Peter Weaver
Melbourne—Alicja Grobtuch
Beirut—O. M. Marashian
Brussels—A. P. L. Gordon
Bombay—Sharokh Sabavala
Zurich—Raymond Shah
Johannesburg—Norman Herd
Milan—Gene DiRaimondo
Stockholm—Curt Agren
Vienna—F. H. Baer

Keith Henney, Consulting Editor

•

Philip H. Hubbard, Jr.
Advertising Sales Manager

R. S. Quint, Buyers' Guide Manager
George Pomeroy, Classified Advertising Manager
Frederic Stewart, Promotion Manager
James F. O'Brien, Business Manager
Hugh J. Quinn, Circulation Manager
James H. Thomas, Market Research Manager

Donald J. Cassidy, New York
Frederick R. Whitmore, Boston
Warren H. Gardner, W. J. Boyle, Jr., Philadelphia
Willis T. Smith, Chicago
Paul T. Fegley, Cleveland
David M. Watson, Pittsburgh
T. H. Carmody, R. C. Alcorn, San Francisco
D. A. McMillan, M. W. Freeman, Los Angeles
D. Billian, M. Miller, Atlanta
Robert T. Wood, Dallas
Jack Patten, Denver
E. E. Schirmer, Norman Strick, London
Stanley Kimes, Frankfurt
Michael R. Zeynel, Geneva

...about NUCLEONICS

Editor Abroad

Hoby Ellis our Associate Editor in charge of Applied Radiation matters is an amazing guy. In a 30-day period from Oct. 16 to Nov. 16 he: (1) Got Married, (2) Honeymooned in 11 countries of Europe including Russia, (3) Got drunk in Moscow with some of the Russians we've hosted in New York, (4) Received first copies of his new McGraw-Hill book "Nuclear Technology for Engineers." An account of the sober but nuclear segment of his visit to Moscow starts on p. 98 of this issue; a review of his book appears on p. 108.

Kills 'em Dead

The Madison Avenue genius who aided the sales of his client's insecticide by coining the phrase "Kills 'em Dead," should read the article on the sterile-male method of insect eradication that starts on p. 74. Large-scale use of this method has eliminated the screwworm fly from Florida without the flies knowing what hit them.

The idea is to raise a very large number of flies in captivity, sterilize them with radiation and then distribute them over the affected area. The sterile male flies satisfy, but do not impregnate, normal females. Since the females mate but once they are doomed to have no young.

The frustrated romance of the screwworm fly provides yet another instance of the successful application of nuclear radiation to practical problems. We've been recounting some of the best of these applications in our continuing series of Applied Radiation Case Histories. The next one, scheduled for this spring, will tell how radiation aided a study of electroplating at the General Motors Research Laboratory.

How Soon to Breed

Nuclear engineers can sympathize with the breeding problems of the screwworm fly, they've got some of their own. The recognized limitations in the supply of naturally fissionable U^{235} mean that someday we must make use of the fertile nuclides Th^{232} and U^{238} to breed fissionable U^{233} and Pu^{239}. Someday—but just when? Different groups have come up with different answers to that vexing problem, depending in part on their assumptions as to the available reserves of uranium and the growth of demand for nuclear power.

We've arranged a debate in print on the question of "Breeding—How Soon a Necessity?"—you'll find it on p. 60. In favor of early attention to the problem is William Ergen of Oak Ridge National Laboratory. Saying that we can afford to wait is Ed Zebroski of General Electric's Atomic Power Equipment Department.

A word or two about the debaters: Ergen first went to Oak Ridge in connection with the aircraft nuclear propulsion activities of Fairchild Aircraft. With the abandonment of the NEPA program he joined ORNL and is now on the Director's staff.

Zebroski's nuclear career goes back to Manhattan District days and the University of California's Radiation Laboratory. His varied activities have included chemical separations technology, project engineering on the Submarine Advanced Reactor at Knolls Atomic Power Laboratory and, his present spot with General Electric.

—The Editors

A McGRAW-HILL PUBLICATION

member of Associated Business Publications and Audit Bureau of Circulations

NUCLEONICS (with which are consolidated "Atomic Power" and "Atomic Engineering"), February, 1960, Vol. 18, No. 2. Published monthly by the McGraw-Hill Publishing Co., Inc., James H. McGraw (1860–1948), founder. **Executive, Editorial, Circulation and Advertising Offices**, McGraw-Hill Building, 330 W. 42nd Street, N. Y. 36, N. Y. Publication Office, 212 East York St., York, Pa. See panel below for directions regarding subscriptions or changes of address. Donald C. McGraw, President; Joseph A. Gerardi, Executive Vice President; L. Keith Goodrich, Vice President and Treasurer; John J. Cooke, Secretary; Officers of the Publication Division; Nelson L. Bond, President; Shelton Fisher, Senior Vice President; John R. Callaham, Vice President and Editorial Director; Joseph H. Allen, Vice President and Director of Advertising Sales; A. R. Venezian, Vice President and Circulation Coordinator. United States Subscription rate for individuals in the field of publication $8 per year; $12 for 2 years; $16 for 3 years. Canada, other Western Hemisphere countries, and the Philippines, $10 for 1 year; $16 for 2 years; $20 for 3 years; all other countries, $15 for 1 year; $25 for 2 years; $30 for 3 years.

Single copy prices: United States, United States possessions, and Canada, $1; elsewhere, $2. Second-class mail privileges authorized at York, Pa. Printed in U. S. A. Title registered in U. S. Patent Office. © Copyright 1960 McGraw-Hill Publishing Co., all rights reserved.

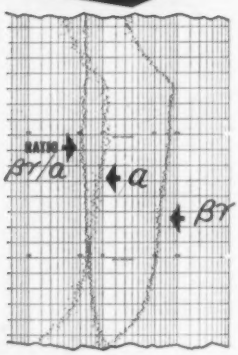
SUBSCRIPTIONS. Send subscription correspondence and change of address to Fulfillment Manager, NUCLEONICS, 330 W. 42nd Street, New York 36, N. Y. Allow one month for change of address, giving old as well as new address, and including postal zone number, if any. If possible, enclose an address label from a recent issue of the magazine. Please allow one month for change to become effective. Subscriptions are solicited from individuals engaged in the design, development and use of atomic power, nuclear engineering and applied radiation. **Position and company connection must be indicated on subscription orders.**

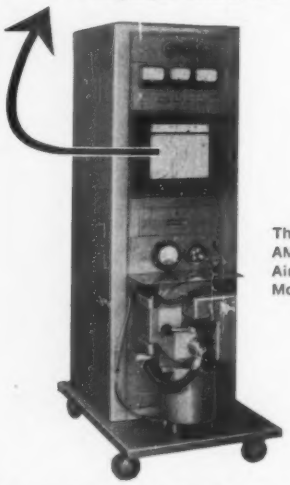
Postmaster. Please send form 3579 to NUCLEONICS, 330 W. 42nd St., N. Y. 36, N. Y.

Leaders in Missiles / Space Technology —
BOOSTER SYSTEMS, ELECTRONICS, GROUND SUPPORT EQUIPMENT, AND NUCLEONICS.

MARTIN

This Air Monitor Solves the Natural Radon Progeny Problem





The New AM-33R Air Monitor

The AM-33R is First to Provide *Direct* Identification of Long Half-Life Emitters

Due to natural radon progeny, identification of long half-life emitters with ordinary monitors means a delay of five hours or more, and requires multiple detectors. Now, with the new AM-33R air monitor, the presence of these emitters can be identified directly, and almost immediately—with a single detector.

PRICES—FOB, INDIANAPOLIS

AM-33R (Moving Filter) Illustrated $6,580.00
AM-22R (Fixed Filter) $5,230.00

FOR DETAILS, PHONE LIBERTY 6-2415 COLLECT

NMC

Nuclear Measurements Corp.
2460 N. ARLINGTON AVE.
INDIANAPOLIS 18, INDIANA
International Office: 13 E. 40th St., New York 16, N. Y.

NUCLEAR REACTIONS

Organic Reactor Progress —a Dissenting Voice

DEAR SIR:

One should be encouraged by the progress made in the field of organic reactors since my contribution on that subject three years ago (NU, Aug. '56, p. 62). I believe, however, that there is undue optimism on the part of the Atomics International contributors (NU, Nov. '59, p. 113 and p. 234) in two areas:

Heat-transfer properties of irradiated polyphenyls. The reduction of only 10% in heat-transfer coefficient due to a 30% high-boiler content in OMRE (as shown in Fig. 1E on p. 113) does not correspond to the change in physical properties shown in other parts of that figure. In other words, the heat-transfer data at appreciable high-boiler content do not correlate by any of the currently accepted equations, such as Sieder-Tate, Diettus-Boelter, etc. If one were to use such an equation on the physical property data for Santowax-R given in Table 1 (p. 120), the coefficient for 30% HB content would be about 20% lower than the curve in Fig. 4 (p. 122), which is apparently inferred from the OMRE results with a somewhat different coolant.

Decomposition rates. Detailed examination of ref. *2* [Gercke and Trilling, "A survey of the decomposition rates of organic reactor coolants," NAA-SR-3835 (1959)] causes question about the statement that ". . . tests . . . confirm the equivalence of organic damage with energy absorbed, regardless of the particle transferring the energy." Data in this report show excellent agreement between damage rates produced by gamma rays and by 1-Mev electrons for the range of 5–15% high-boiler content. At 30% high-boiler content (γ-ray data do not extend that far), the $G_{coolant}$ value for electron irradiation is 0.086 vs 0.15 for OMRE irradiation (28% of energy due to fast neutrons). Assuming equivalence of gammas and electrons, the authors have calculated neutrons to be 3.7 times as effective as gammas in producing coolant damage. Extrapolating to a large reactor, they obtain a higher damage rate by about 60% due to the larger fraction of fast-neutron energy. The coolant makeup cost is then slightly over 1 mil rather than 0.66 mil/kwh(e). There also are indications in the literature that the gaseous decomposition products formed in-pile and in a Van de Graaff are different, suggesting possibly different damage mechanisms.

—G. A. FREUND
Reactor Engineering
Argonne National Laboratory
Lemont, Ill.

Of Mice and Men and Irradiated Food

DEAR SIR:

I have been asked by Dr. Hermann Kraybill of the Curtiss-Wright Corporation to critically review the article: "Are Irradiated Foods Harmful?" (NU, Jan. '60, p. 112), and to submit my comments, if any, to you.

With respect to the heart lesions that I have observed in some mice on the irradiated diet only, I wish to state that the search for an etiologic agent is still in progress. There is always the possibility that the auricular damage may be reproduced, in which case some irradiated food will be implied as a carrier of the causative factor.

At the present time I do not hesitate to take a stand with Dr. Kraybill in this matter. The irradiated-food project has a scientific potential that should be exploited to the fullest extent. This can only be accomplished if investigation in this area is encouraged rather than discouraged and curtailed. The advent of new tools for scientific exploration, as a direct result of recent and impressive advances in nuclear physics, enables the investigator to devise new experimental environments and consequently new challenges to the living cell. Under such circumstances, the complexity of cellular metabolism precludes the formulation of any theories as to what the response may be. The unusual should be expected and appreciated if basic research is to progress.

—HARRY MONSEN
Assistant Professor of Anatomy
University of Illinois
Chicago, Illinois

[EDITOR'S NOTE: Letters from other wholesomeness investigators have been received by NUCLEONICS supporting Dr. Kraybill's point of view. Reprints of Dr. Kraybill's article are available.]

Reprints Available

Applying Radiation in Industry
May '56 Special Report
$1.25

How Radiation Affects Materials
Sept. '56 Special Report
$1.35

Analog and Digital Computers in Nuclear Engineering
May '57 Special Report
$1.25

Tenth Anniversary
Sept. '57
$.75

Fuel for the World's Reactors
Aug. '58
$.50

Critical Facilities
Dec. '58
$.50

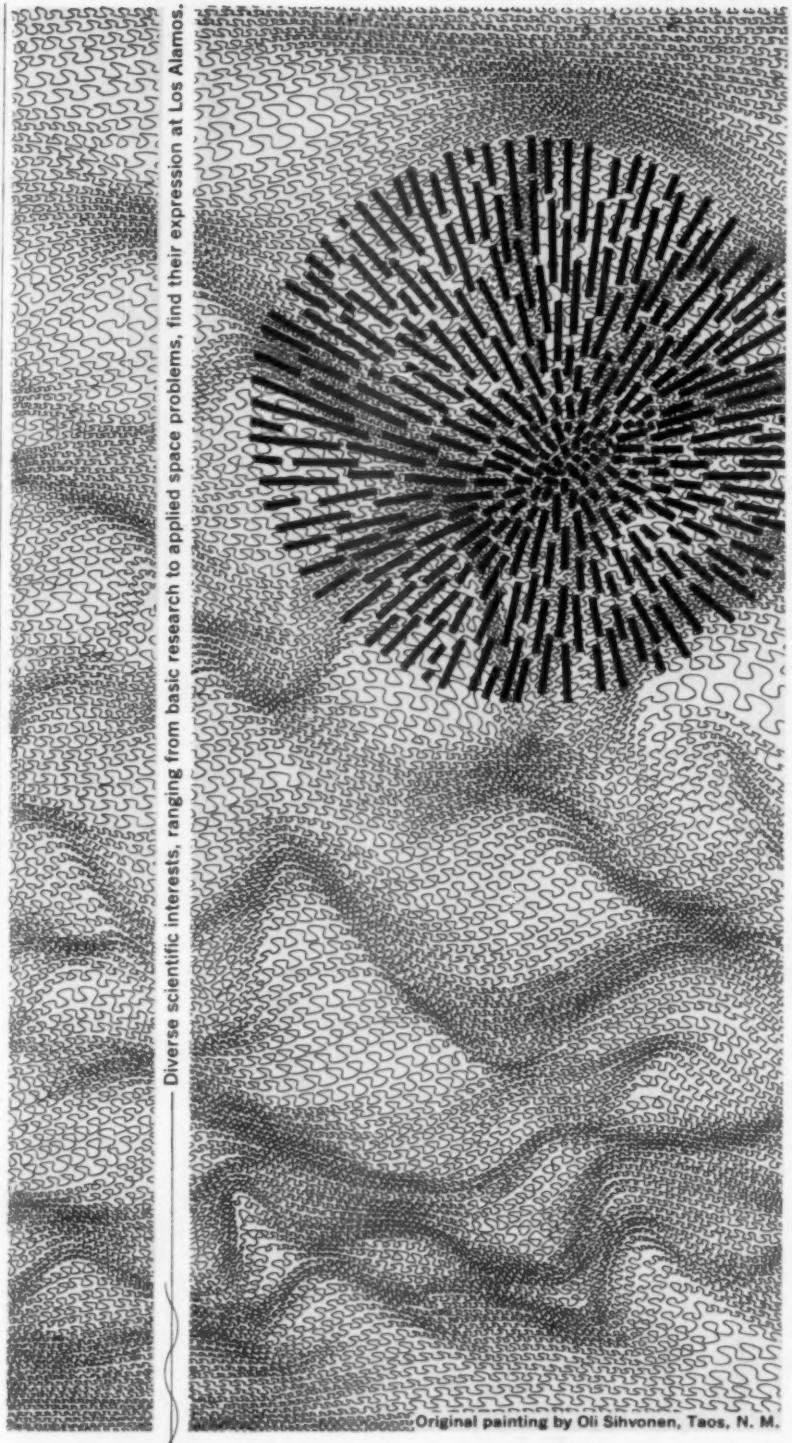
Nucleonic Instrumentation
June '59
$1.00

Measuring Large Radiation Doses
Oct. '59
$.75

Also
Reactor on the line Series
No. 1—EBWR
No. 2—APPR
No. 3—SRE
No. 4—VBWR
No. 5—PWR
No. 6—ORR
No. 7—ALPR
No. 8—Dresden
each 25¢

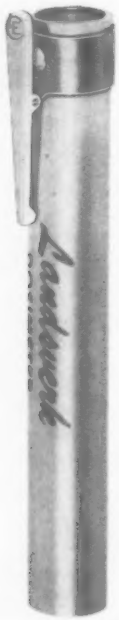
Reprint Dept.

NUCLEONICS
330 W. 42nd St.
New York 36, N. Y.


Diverse scientific interests, ranging from basic research to applied space problems, find their expression at Los Alamos.
Original painting by Oli Sihvonen, Taos, N. M.

For employment information write: Personnel Director, Department 60-17

los alamos
scientific laboratory
OF THE UNIVERSITY OF CALIFORNIA
LOS ALAMOS, NEW MEXICO



Model L-50 is a hermetically sealed dosimeter of the 0-200 milliroentgen range. It uses the same rugged type quartz fiber voltmeter which is used in all Landsverk quartz fiber instruments. Designed with a self contained microscope system to allow the wearer instant knowledge of the radiation to which he has been exposed in a given period of time. Its energy dependence is less than 10% from CO^{60} to 50 kev. Accuracy is ±10% of true dose at midscale. Linearity of scale is within ±3%. Inherent electrical leakage is less than ±2% per 24 hours.

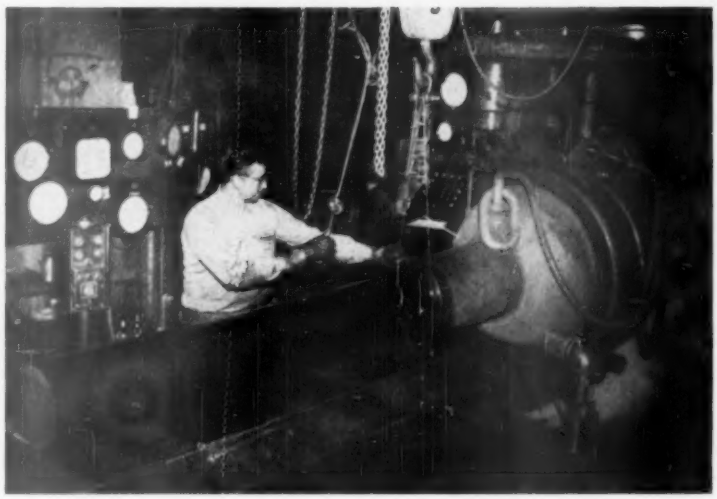
THE STANDARD OF QUALITY IN DOSIMETRY

Model L-24K is a rugged, battery operated dosimeter charger. Designed as a versatile unit it can be used effectively in the laboratory as well as in field use. The charging unit is built into one end of a ruggedly constructed, leatherette covered carrying case with twelve clips mounted into the cover and over the battery compartment to hold dosimeters securely while in storage or in transit. A single potentiometer provides the only control needed to vary the charging voltage supplied by eight 22½ volt No. 412 Minimax Batteries. A single 1½ volt size D cell provides power for the light system. The model L-24K can charge all Landsverk commercial direct reading dosimeters quickly and dependably.

"The first name in dosimeters" *The Landsverk Electrometer Company*

THE LANDSVERK ELECTROMETER COMPANY / 641 SONORA AVENUE / GLENDALE 1, CALIFORNIA

GLC GRAPHITE SERVES NUCLEAR REQUIREMENTS THROUGHOUT THE WORLD



The uniformly high quality of GLC graphite for nuclear applications has been proved out in thermal columns and reflectors in operation throughout the world, as well as sub-critical assemblies installed in Universities in the United States.

We are equipped and staffed to supply a superior graphite promptly and economically for nuclear applications of all kinds. Our facilities for expediting both domestic and overseas shipments are excellent.

You may find it advantageous to extend to us the opportunity of quoting on your nuclear graphite requirements.

PRODUCTS ELECTRODES GLC DIVISION YOU CAN TRUST

GREAT LAKES CARBON CORPORATION

18 EAST 48TH STREET, NEW YORK 17, N. Y. OFFICES IN PRINCIPAL CITIES

Breakthrough in Radiation Detection!

The new Hughes Solid State Detector (housed in the transistor can on the tip of this complete alpha survey meter) is the smallest...fastest...simplest...and most accurate charged particle detector ever devised.

SMALL: 1mm square—1cm square
FAST: Response time less than one nanosecond
SIMPLE: Operates on 6-12 volts
ACCURATE: Better than 1% particle energy resolution.

Hughes is already providing equipment using these detectors in conjunction with fast electronic circuits, memory devices and read out equipment.

Hughes Nuclear Electronics Laboratory specializes in radiation——its measurement, production and application——with off-the-shelf products, custom products, research studies, and design and construction of facilities. We welcome your inquiry.

Please write, wire or call:
Mr. Ben W. Davis, Hughes Nuclear Electronics Laboratory, P.O. Box 90515-A, International Airport Station, Los Angeles 45, California

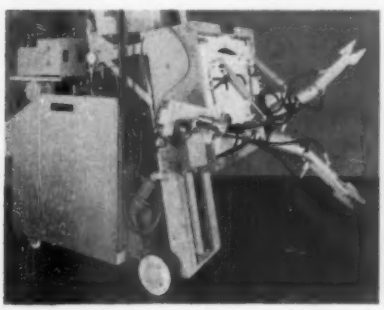
Creating a new world with ELECTRONICS

HUGHES

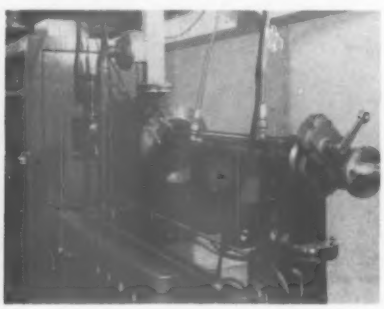
© 1960 HUGHES AIRCRAFT COMPANY

Hughes offers you complete, proven capabilities in radiation... detectors, handling equipment, sources, analysis of effects

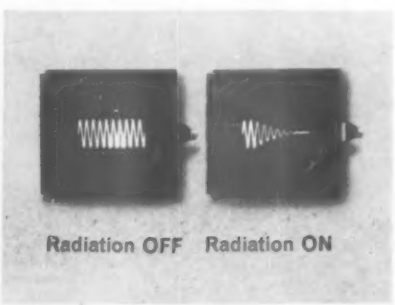
MOBOT Mark I is first of a family of mobile, remote controlled handling machines using TV vision and electronic controls. Wall or crane mounted Mobots and rough terrain Mobots are among those currently under development.



Hughes Research Linac has 3 times the current of comparable machines...over ½ amp. available at 1 to 10 μs pulse width. They are available in many configurations for research in the effects and other applications of high gamma radiation.



Shown is the effect of pulsed (low dose, high rate) radiation on a vacuum tube amplifier. For the past three years Hughes has been studying transient and permanent radiation effects on materials, components and systems.



WRONG WAY TO LIGHT A NUCLEAR REACTOR

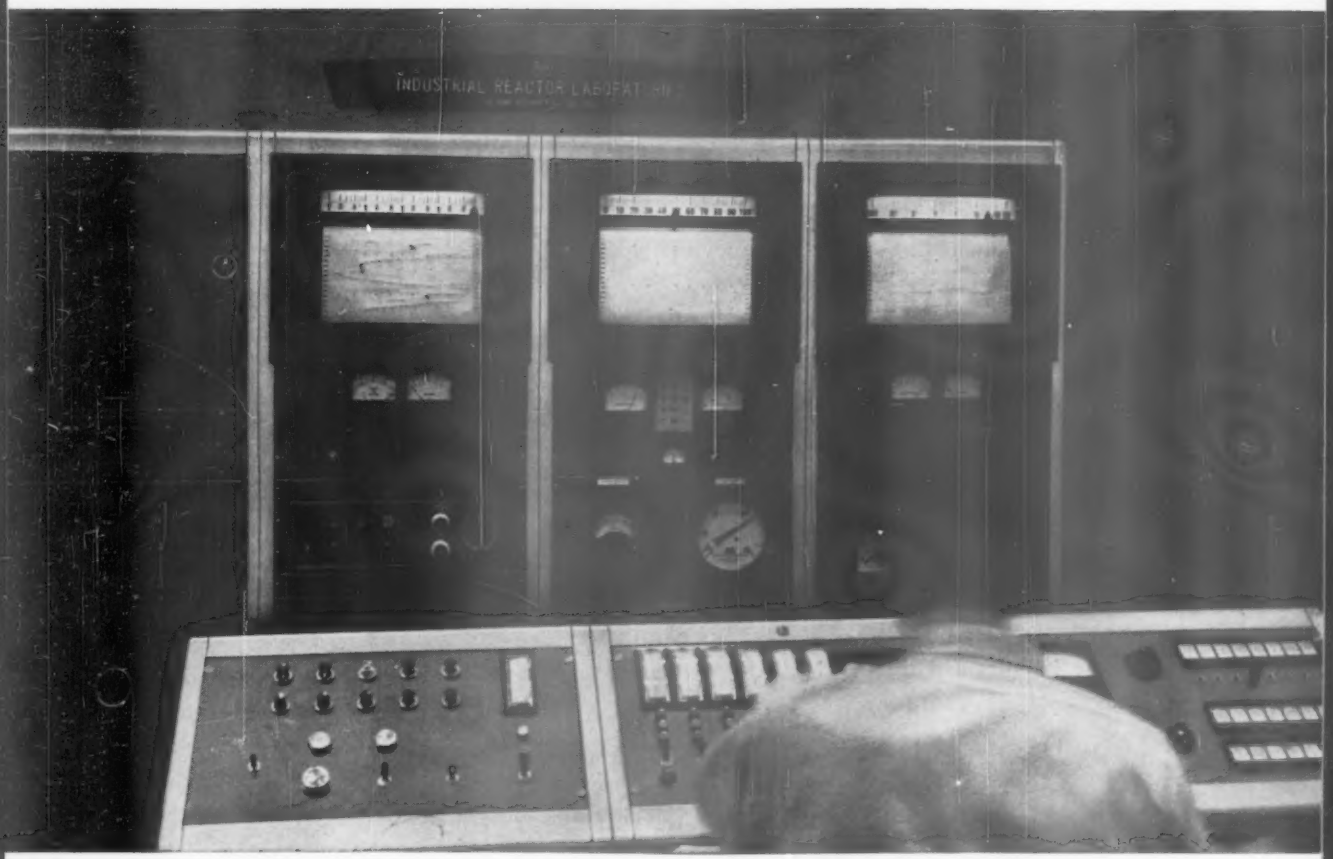
Initiating a nuclear reactor fuel fabrication program with disregard of the resulting cold scrap is like burning money! Davison, as the largest reprocessor of uranium cold scrap, quickly converts useless, but expensive, uranium scrap into AEC credit amounting to thousands of dollars. If you operate a reactor or fabricate fuel for a nuclear reactor, you gain a distinct advantage by consulting Davison on the economical collection, segregation and storage of uranium scrap before it is created. Contact Davison today.

DEPARTMENT A-302

W.R. GRACE & CO.

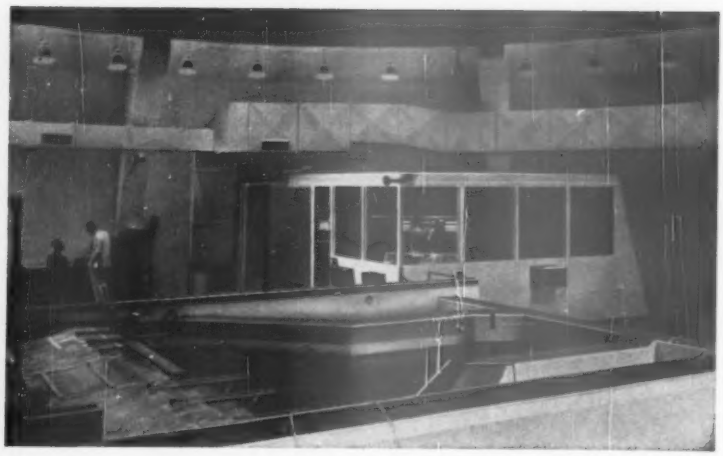
DAVISON CHEMICAL DIVISION

ERWIN, TENNESSEE



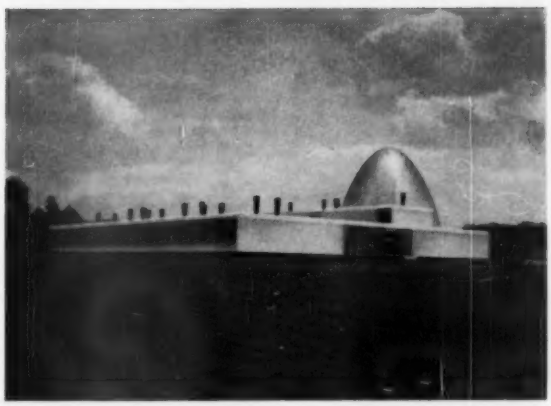
at the "Atoms for Living" Center . . .

10 companies share Honeywell



This view shows the top of the "swimming pool" and the reactor control room. A core of enriched uranium is located at the bottom of the pool, 30 feet below. 136,000 gallons of demineralized circulating water provide additional shielding and remove heat from the core when the reactor is operating.

Honeywell instruments for startup, linear, log N, and safety channels, along with auxiliary equipment, are mounted on the panel to provide good readability from the operator's position at the console. Rod drive, power set, range selector, rod position indicators, scram button, scram warnings, and secondary annunciator system are on the console within easy reach.



An 87-foot-high aluminum-sheathed concrete dome houses the reactor, and is designed to provide maximum safety from radiation hazards.

instrumentation for safe reactor control

Ten non-competing industrial companies were in need of facilities for nuclear research in their respective fields of interest, so they pooled their resources to form Industrial Reactor Laboratories, Inc.—an "Atoms for Living" center near Plainsboro, N.J. Now, each company has at its disposal the world's largest privately owned nuclear research reactor—at one-tenth the cost of single-company ownership. IRL owners are American Machine & Foundry Company, American Tobacco Company, Atlas Powder Company, Continental Can Company, Corning Glass Works, National Distillers and Chemical Corporation, National Lead Company, Radio Corporation of America, Socony Mobil Oil Company, Inc., and United States Rubber Company.

The reactor is a 5-million-watt "swimming pool" type, designed and built by American Machine & Foundry Company. Like many major nuclear installations in the country, Industrial Reactor Laboratories use Honeywell instrumentation for safe, accurate, dependable control. In your own project, use Honeywell's extensive experience in control of nuclear processes—experience that includes design and construction of reliable components, building complete reactor control systems, and actual installation and startup. Call your nearby Honeywell field engineer. He's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.

75th YEAR
PIONEERING THE FUTURE

Honeywell

H HONEYWELL *First in Control*

SINCE 1885

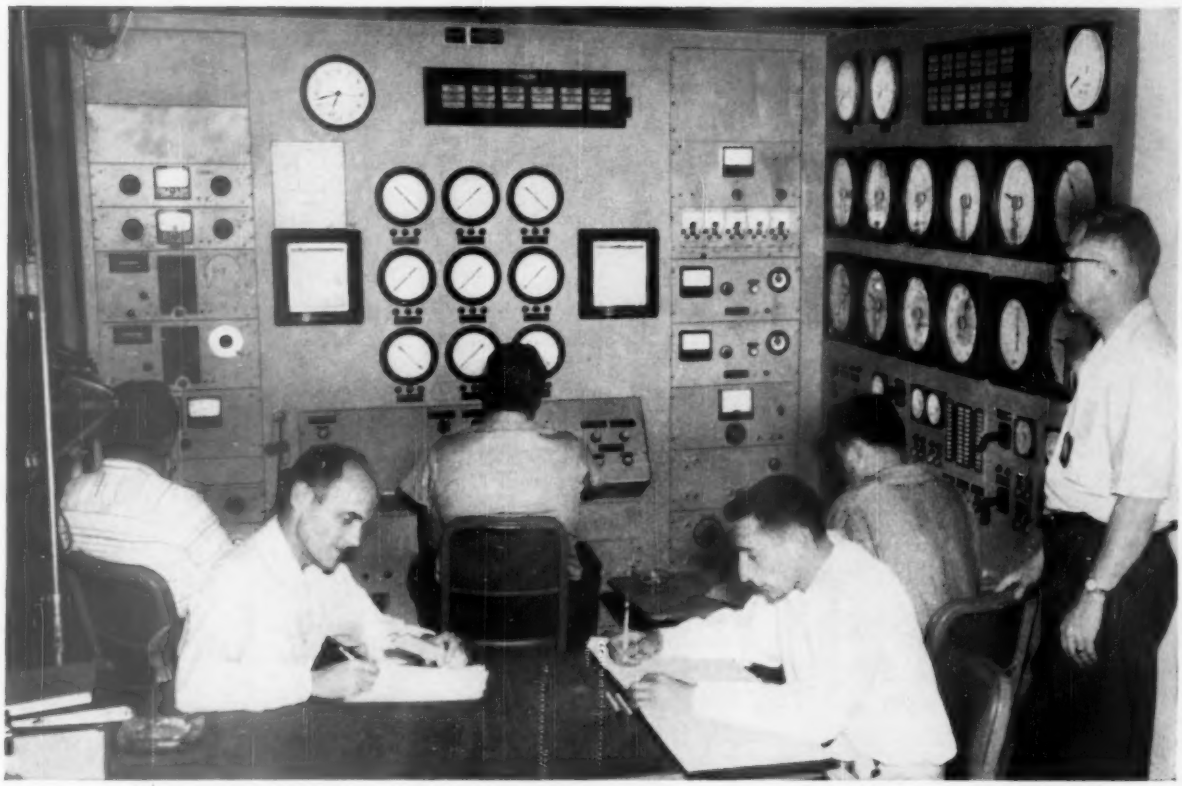
Zirconium

Semi-finished products of Zirconium and Zirconium alloys

Nuclear grade

PECHINEY Division Applications Atomiques

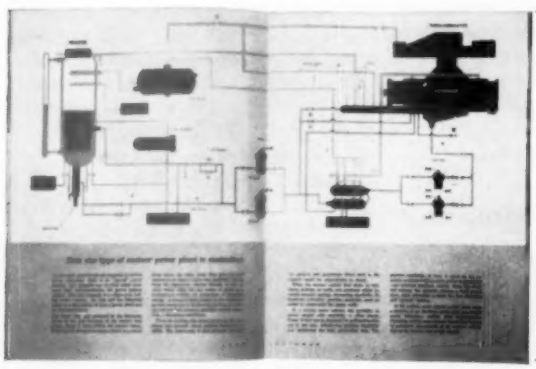
23 RUE BALZAC PARIS 8e



SL-1 Reactor controls for Arctic supplied by L&N

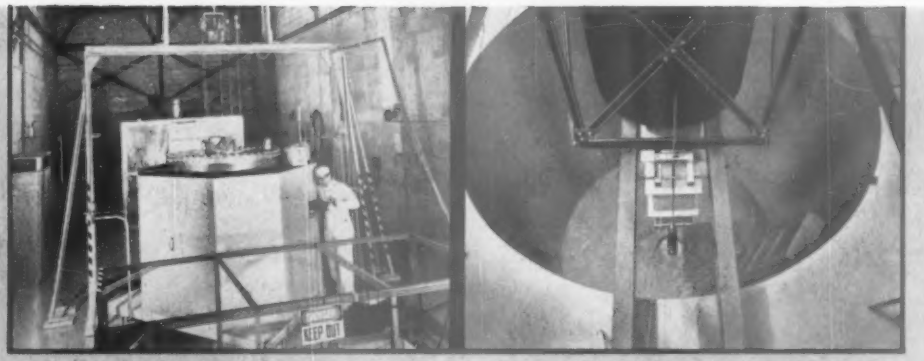
Designed as a "package" power plant for remote arctic installations, the SL-1 built by Argonne National Laboratory for the U. S. Atomic Energy Commission will supply electric power for radar equipment and space heating for offices and barracks. One of its many outstanding advantages . . . the reactor is expected to operate for three years with a single fuel loading, and during this time, continuous supervision may not be necessary. This calls for instrumentation of simple design . . . instrumentation that is *dependable*. The Leeds & Northrup control system selected for the SL-1 meets these requirements with proven, economical components.

Four major automatic systems—steam by-pass control, main steam pressure control, air-cooled condenser control, and three-element feedwater control—are incorporated in the design. These integrated L&N systems can be depended upon to function under arctic conditions . . . to assure the safe, reliable control so vital to successful reactor operation.



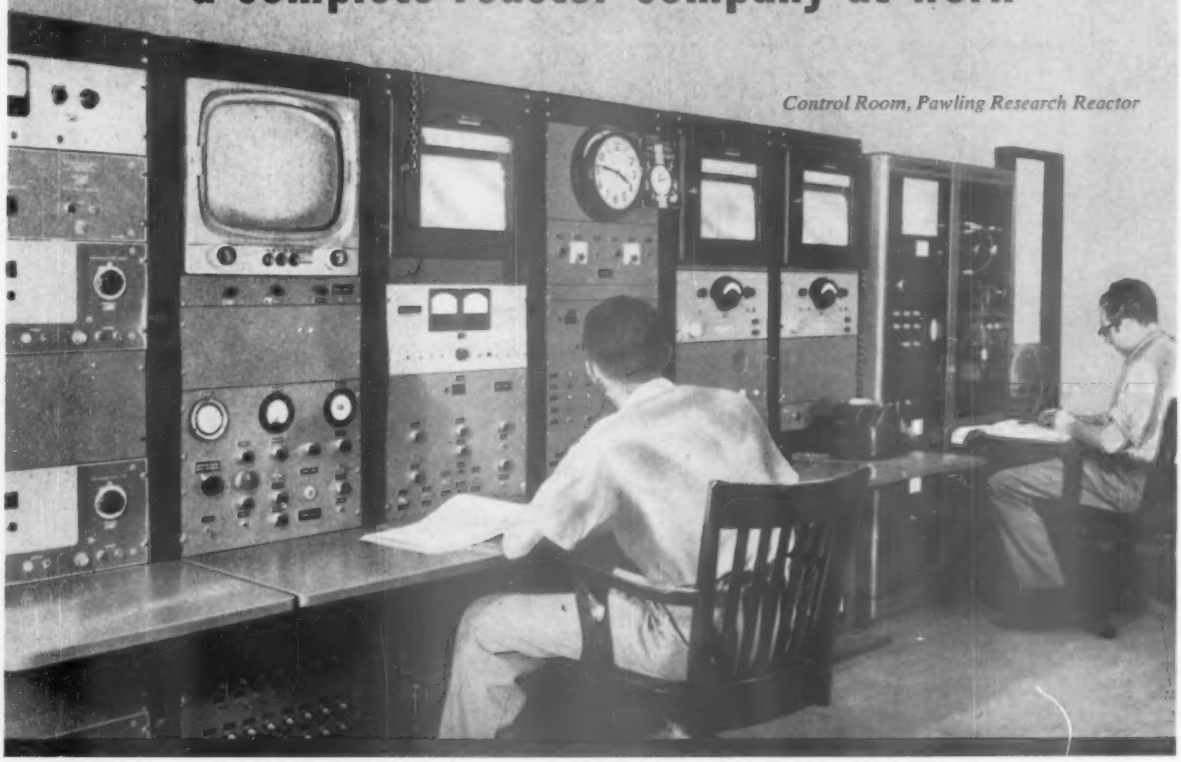
For helpful information *on nuclear controls, ask for a copy of our publication "Nuclear Power Reactor Control Systems" by writing Nuclear Systems Group, Leeds & Northrup Co., 4936 Stenton Ave., Philadelphia 44, Pa.*

LEEDS & NORTHRUP
Instruments — Automatic Controls • Furnaces



Pawling Research Reactor *Gamma Ray Experiment*

a complete reactor company at work



Control Room, Pawling Research Reactor

A reactor company's ability to gain the best solution with a given set of design parameters is proportional to the quality of its experimental physicists. This is why NDA maintains an experimental physics group that has gained a wide reputation for quality and productivity.

This group's working tools include the Pawling Research Reactor and critical facility, a major mathematics center with Datatron Computer and a hot lab (10,000-curie capacity) for chemical confirmation of the experimentalist's work. In addition to use of its own facilities, NDA has carried out programs based on the high neutron fluxes available at the National Reactor Testing Station in Idaho.

NDA's experimental physics group conducts complete reactor core and shielding physics programs. It also addresses itself to specific problems such as exponential and single cell experiments, reactivity value studies and related projects to which the experimental physicist brings unique insights and skills.

Working for itself and others, NDA participates in reactor development on a broad front. As a result, it offers unusual opportunities for experimental physicists and other reactor scientists and engineers to grow with the company and the industry. Write for employment information.

a complete reactor company

NDA — **NUCLEAR DEVELOPMENT CORPORATION OF AMERICA**

5 NEW STREET, WHITE PLAINS, N. Y. TEL. WH. 8-5800

NDA EUROPE 31, Rue du Marais, Brussels, Belgium

ROUNDUP of Key Developments in Nucleonics

AEC's Fiscal '60 Reactor Projects Getting Off Ground

AEC last month completed the groundwork for construction of all but one of the reactors in its fiscal-'60 building program—both those AEC-funded and those jointly sponsored by AEC and private industry.

Meanwhile, however, there were indications that industry might have to be satisfied for fiscal '61 as well with these reactors as AEC's entire contribution to the reactor-building effort. For it began to seem that AEC might simply have run out of developmental power reactors to build, from which to make up a '61 program—except for a 300-Mw(e) pressurized- or boiling-water reactor that the Commission is understood to have been interested for some time in seeing built.

Developments last month on the '60 program included:

- Receipt of five proposals in answer to AEC's call to public power groups to operate a 16.5-Mw(e) unit it calls SSPWR (for Small-Sized Pressurized Water Reactor), to be built by AEC under the ground-rules of the second round (Piqua, Elk River) of the Power Demonstration Reactor Program.
- Signing of a contract between AEC and the Puerto Rico Water Resources Authority for construction of the $11-million, 16.3-Mw(e) BONUS (BOiling NUclear Superheat) reactor.
- Receipt of an unsolicited proposal jointly from Consumers Power Co. of Jackson, Mich., and General Electric to get AEC aid on their project to build a 50-Mw(e) boiling-water reactor plant at Big Rock Point, Mich. AEC has $5-million available to aid unsolicited projects.
- Issuance of an AEC invitation to bid on two 50-Mw(e) prototype reactors, one boiling-water, one organic-moderated and -cooled.
- Issuance of another AEC call to publicly- or cooperatively-owned utilities to provide conventional generating equipment for, and to operate, an intermediate-size boiling-water prototype plant.
- Selection of Fluor Corp. as architect-engineer on OMRE-2, which AEC is now calling the Experimental Organic-Cooled Reactor. Atomics International will help with the nuclear design, as subcontractor to Fluor.

However a '59 program holdover—the natural U heavy-water reactor—may not make the grade. It was originally authorized in fiscal '59, when $4.5-million research-development money was granted; but a construction start is still not out of discussion stage. Many in AEC feel the technical difficulties of the system do not warrant the expenditure at this time, especially in view of the cordial relations with Canada where this concept has been the subject of long and intensive effort.

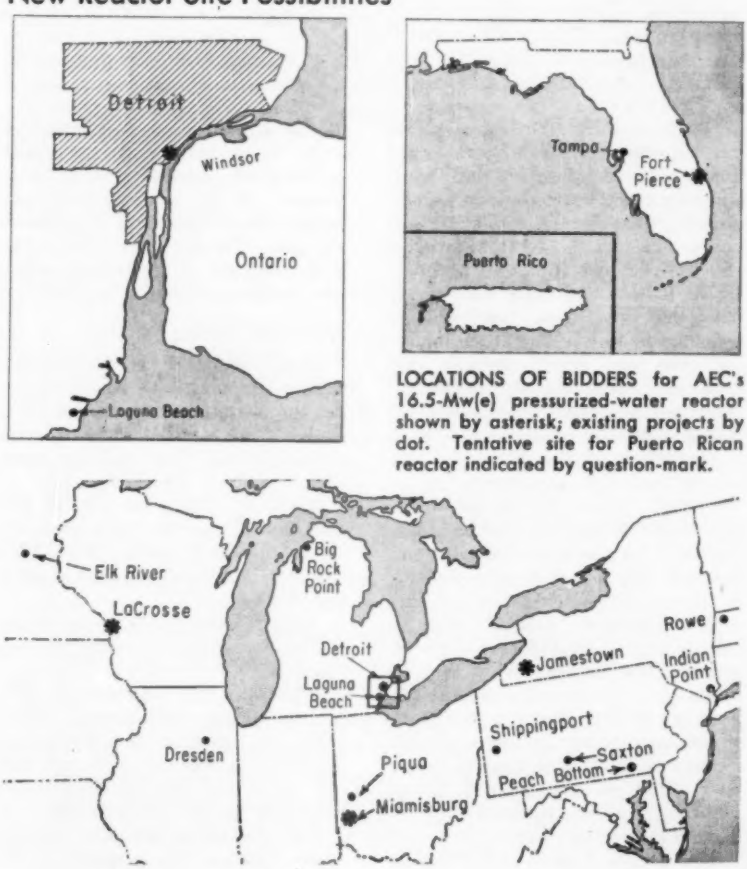
REACTOR FOR PUERTO RICO

The Puerto Rican project—PRWRA had been trying to get a developmental reactor for the island since early 1957 (NU, May '57, 24)—is under the technical responsibility of General Nuclear Engineering Corp. division of Combustion Engineering; GNEC has designed the unit. A construction contractor, not yet chosen, will purchase hardware, by components, at competitive bidding.

PRWRA will provide the site and all conventional equipment including turbogenerator, to cost $3.1–3.5-million (the agency has already invested another $200,000 in training and studies). The site being recommended to the Advisory Committee on Reactor Safeguards is at Punta Jiguero, the island's westernmost tip; it is 15 mi NW of the originally-proposed site on the outskirts of Mayagüez, Puerto Rico's third largest city. A hazards report is now before AEC's hazards evaluation group, with which PRWRA will meet early this month; the report then goes to ACRS. PRWRA hopes to have clearance to use the site in time to break ground there in June.

The reactor's thermal output will

New Reactor Site Possibilities



LOCATIONS OF BIDDERS for AEC's 16.5-Mw(e) pressurized-water reactor shown by asterisk; existing projects by dot. Tentative site for Puerto Rican reactor indicated by question-mark.

AEC's Reactor Projects Authorized in Fiscal '60

Reactor	Utility	Mfr.	Arch.-Eng.	Output (Mw(e))	Cost (10^6) AEC auth'd. to spend	Cost (10^6) AEC has oblig'd.	Cost (10^6) Total	Location	Completion
CIVILIAN POWER REACTORS									
AEC-Industry Partnership									
Small-Size Pressurized Water (SSPWR)	5 bidders	?	Gibbs & Hill	16.5	10	0.2	12–14.5	?	May '62
High-Density Boiling Water	Consumers Power	GE	Bechtel	50–75	[3	—]		Big Rock Pt., Mich	late '62
[Unsolicited Bids]					5	—	27		
Improved-Cycle Boiling Water	Bids due May	Bids due April	?	50–75	10	—	?	?	'63–'64
Intermediate Organic	Bids due April	?	?	50–75	8	—	?	?	'63–'64
High-Temp. Gas-cooled (HTGR)	Phila. Elec.	General Atomic	Bechtel	30–40	14.5	14.5	39	Peach Bottom, Pa.	Dec. '63
Entirely AEC-funded									
Experim. Gas-cooled (EGCR)	—	?	H. K. Ferguson	25	30	4.2	30	Oak Ridge, Tenn.	late '62
Process Heat Desalinization (ELPHR)	none	?	Sargent & Lundy	40(th)	4	0.328	4	Pt. Loma, Calif.	early '62
Experim. Organic (EOCR, ex-OMRE-2)	none	?	Fluor (with AI)	20–40(th)	6	<0.1	6	NRTS, Idaho	late '62 or early '63
Boiling Nuclear Superheat (BONUS)	P.R. Water Resources Auth.	?	GNEC div., Comb. En.	16.3	11	—	11	Puerto Rico (Pta. Jiguero?)	early '63
OTHER REACTORS									
Nuclear Test Plant (NTP), Army	none	Comb. En.	C. F. Braun	60(th)	5	0.2	5	NRTS, Idaho	—
Natural Circulation (NCR), Navy	none	KAPL	KAPL	?	18.5	18.5	18.5	NRTS, Idaho	mid-'62
High Flux Beam	none	?	Lummus	20–40(th)	10	0.75	10	Brookhaven	1963

be 50 Mw—37 in the boiler, 13 in the superheater—for 17.3 Mw(e) gross, 16.3 net. Coolant water will enter the reactor at 354° F and leave as 900°, 900 psi steam. The central boiler zone in the 4½-ft high core will use zircaloy-clad UO_2 pellets at 1.85% enrichment, and will make 534°, 900 psig steam. This will be collected by ring piping at the top of the core and passed through the peripheral superheating elements: stainless-steel-clad oxide pellets at 3.5% enrichment.

Placement of the boiler in the center and the superheater as a peripheral annulus is just the opposite of the design adopted by Allis-Chalmers for the Sioux Falls reactor, the only other project, save for one in Russia, embodying integral nuclear superheat. GNEC says it adopted its design for reasons of safety (less nuclear sensitivity to flooding and voiding); heat transfer (not good with steam cooling, so superheater is put in lower power-density region); and neutron economy (stainless steel placed where neutrons are leaking anyway, conversion ratio stepped up).

One unique feature of the design is the containment philosophy: a large dome enveloping the entire power plant, permitting use of lower pressure (5 psi maximum) by enlarging the volume, and thus lowering cost. Present plans, still under study, call for a 160-ft steel hemisphere sitting on a 20-ft high wall.

FIVE FOR SSPWR

Five municipal or cooperative utilities responded to AEC's invitation of last August to take a 16.5-Mw(e) pressurized water reactor power plant on their grid and operate it. They were the City of Miamisburg, Ohio; the City of Detroit, Mich.; the City of Jamestown, N. Y.; the City of Fort Pierce, Fla., and the Dairyland Power Cooperative, La Crosse, Wis.

A quick NUCLEONICS survey of the five bidders revealed several interesting points:

• Despite the importance AEC had previously indicated it would place on inclusion of superheating apparatus in the bids, only one bidder—Dairyland Power Cooperative—offered to finance a superheater.

The original invitation, which left to the option of the proposer the installation of fossil-fired superheating equipment, was later amended to require that a conventional superheater be included in the project. The superheater, boosting plant capacity to 22 Mw(e), will be provided by AEC if necessary, however, as part of the reactor steam-generating plant; but proposals under which the bidder provides the superheater "will merit favorable consideration" by AEC.

• All four municipalities bidding proposed to locate the reactor at sites within their city limits. Detroit would locate near George S. Patton Park, at the foot of Morrell St. along the Detroit River and a scant quarter-mile across it from Canada. Ft. Pierce specified a site one block from the heart of its business district, and offered an alternative site half a mile north of city limits. Jamestown would put the reactor on Steele St. on a city-owned tract. Miamisburg's site is described as south of Mound Ave. on a seven-acre municipally-owned tract. Dairyland, however, designated a more remote site, 20 miles south of La Crosse, outside the town of Genoa.

• With but one exception, all bid-

ders cited the rapid rate of increase of their power requirements as the principal reason spurring submission of their proposal. Basically, all five organizations were interested in the potential of atomic fuel, and believed their curiosity would be slaked most economically through such a joint project. One bidder unabashedly emphasized the publicity value expected to be gained from participating in a "nuclear venture."

• None of the bidders' present generating capacity is adequate to accommodate the additional nuclear power at full installed power capacity after a reactor is added to its grid, but only two bidders indicated willingness to purchase additional generating equipment. In any case, AEC would like to see the reactor operated at base load.

• Bids ranged from $2- to $4.5-million, which would bring the total cost of the powerplant, including the proposer's contribution, to $12–14.5-million.

SSPWR will be built under the second-round rules. This means AEC will build and own the reactor; the utility will provide plant site and turbogenerating facilities, buy steam for the latter from AEC and operate the entire plant.

SSPWR Schedule

The following tentative project schedule has been assigned:

Gibbs & Hill, previously selected by AEC as architect-engineer for the project, to proceed at once with conceptual design of the entire project including turbogenerating facilities.

March 15, 1960—Completion of Title I (preliminary) design, comprehensive engineering analysis, and project cost estimates.

April—Contract award to successful bidder.

June—Begin plant construction.

End 1960—Completion of Title II (detailed) design and construction drawings.

May 1962—Reactor critical.

CONSUMERS POWER

The joint bid by Consumers Power Co. and GE actually corresponds to not one but two AEC reactor projects. The explanation of how this came about goes back to the drafting of the 1960 authorization bill, in which nine developmental civilian power reactors were provided for—including a high-density-core boiling water unit toward the cost of which AEC was authorized to contribute $3-million. In addition, the bill contained—in a different section—$5-million to be used to support unsolicited proposals made by industry to AEC; this new measure of flexibility granted AEC by Congress was a result of the newfound cordiality in the working relationship between AEC Chairman McCone and JCAE Chairman Anderson.

Independently, meanwhile, Consumers Power decided to buy a GE high-density boiling water reactor. It naturally wished to avail itself of the financial aid for research and development that AEC had available for just such a reactor, but was understandably reluctant to go through the required competitive-bid procedure after already having come to terms with GE. The solution: to seek AEC aid under the "unsolicited proposals" proviso. The separate $3-million authorization tagged for the high-density boiling reactor will now probably be carried over against '61 reactor development fund requests.

Intermediate Reactors

BWR. Bids will be due at AEC May 4 by publicly- and cooperatively-owned utilities to provide a site and a turbogenerator for and to operate the 50–75 Mw(e) boiling water prototype, and April 4 from manufacturers to design, develop and build the reactor. AEC says improved design of this plant, designated Improved Cycle Boiling Water Reactor, should eliminate the physical complexity of the dual-cycle.

OMR. On the intermediate organic-moderated and -cooled reactor, likewise of 50–75-Mw(e) output, not only publicly- and cooperatively- but also privately-owned utilities may bid, by April 4. However, unlike the Improved Cycle Boiling Reactor, this organic plant is to be built not under second but under third-round rules: the successful utility will "be expected to design, construct and operate the entire plant"—that is, to make its own arrangements with a reactor manufacturer. The proposed plant would use forced convection cooling, would produce steam at 600° F or higher; use of improved fuel such as UO_2 clad with sintered aluminum powder, should increase fuel surface temperature, fuel burnup, and thus reduce power cost.

In the case of both these reactors, AEC may build if no acceptable industry proposal is forthcoming.

Experimental Organic Unit

In contrast to the intermediate organic reactor, the $6-million experimental organic project on which Fluor and Atomics International are getting started will be a flexible, non-power-generating facility designed for experimentation to develop economic organic power reactors. Its flexibility will be such as to permit operation at levels ranging from 20-Mw(th) and 700° F to 40-Mw(th) and 500° F to simulate a wide spectrum of operating conditions. It will also be able to irradiate simultaneously a number of different types of fuel elements and different organics.

AEC's new budget slashed by $140-million

A slash of $140-million from this year features AEC's share of the new federal budget presented to Congress: $2.66-billion for fiscal '61, against $2.80 in fiscal '60. Spending level next year will remain about the same, at $2.6-billion. The new budget preliminarily asks $102-million for reactor construction, civilian and military, compared with $190-million in '60. This includes $24-million for an advance, high-flux test reactor (NU, Jan. '60, 26). Operating funds set for civilian power reactor development are $178-million ($166-million in '60).

Asked for joint AEC-industry reactor projects: $25.4-million (up from $19.6-million); for authorization on construction, $25-million (unchanged). Research-development operating funds include $436.2-million for reactors, civilian and military; $159-million for physical research; $54-million for biology and medicine; $12-million for isotope uses and Plowshare. Another $158-million is for construction of research facilities in these four categories ($114-million of it for reactors). Military reactors would get $227-million ($15-million Army, $85- Navy, $73- Air Force, $40-missile propulsion, $14-million SNAP—auxiliary satellite power).

Fossil Fuels Squeeze French Program

PARIS

With coal stocks way up, with natural gas pouring from the Lacq field in the Southwest, with substantial crude oil and natural gas reserves in the Sahara Desert, France has never had it so good for classical energy resources—and a long-term squeeze on the nuclear energy program is in sight.

Two year-end moves by the de Gaulle government made it clear that for the next few years at least nuclear power will have practically stepchild status in France. In a long speech detailing for the National Assembly the government's energy policy, Minister of Industry Jean-Marcel Jeanneney talked of coal, natural gas, oil and hydroelectric resources, said nothing about nuclear power. And in its budget for 1960, the government lopped $46-million off the $200-million appropriation asked for by the Commissariat à l'Energie Atomique (CEA).

Still another squeeze has come from the stiff initiation fee that France must pay to join the bomb-holders' "Nuclear Club." An $84-million slice of the 1960 military budget is earmarked for nuclear weapons development by CEA.

The impending aerial explosion of the French bomb has been described by CEA High Commissioner Francis Perrin as "without scientific interest." Probably the only nonpolitical benefit from membership in the Nuclear Club is the U^{235} isotope separation plant that is part of the weapons program. France's nuclear power program still remains hitched to plutonium for the long run, but an isotope separation plant is good insurance and certainly strengthens the French bid for nuclear independence. The plant, now under construction at Pierrelatte (NU, Oct. '58, 23), will take about four years to build; $14-million has been ticketed for this year's work.

Two New Projects

Despite the squeeze, CEA will get under way this year two important new projects—a fourth big research center and a 100-Mw(e) prototype power reactor. Both projects indicate a future move away from the natural U, graphite-moderated gas-cooled reactors that France has built so far.

The new power reactor, EL-4, will be natural U fueled and gas cooled but moderated with heavy water, most likely American. Target date for criticality has been set for 1963–64; the site has not been picked yet; Marcoule is a good bet.

At Cadarache, the new research center 30 mi NE of Marseille, CEA will build its first fast reactor, Rapsodie, fueled with an enriched-uranium-plutonium mixture and cooled with liquid sodium. Rapsodie, CEA hopes, will sire a line of breeder reactors for France. The Cadarache equipment list includes two other experimental reactors: Pégase, a swimming-pool type for fuel-element tests, and Gazelle, a "medium temperature" reactor. (The project to develop a high-temperature reactor to produce gas at temperatures to 1300° F has been abandoned.) Pégase will be built in two stages: the first stage, essentially the enriched uranium core, is slated to go critical late this fall. With the three at Cadarache, France will have a dozen experimental reactors in operation. A nuclear submarine, Q-244, for which France has been hoping to obtain a Westinghouse S5W reactor (NU, June '59, 25), is still planned.

Some Problems Still Left

Although in this fourth year of the second five-year (1957–61) nuclear development plan France appears headed toward a far-off round of more-advanced types of reactors, the first round of natural-U-graphite-gas reactors is still a long way from being wrapped up. When the year began, G-3 at Marcoule had not yet gone on the line some six months after going critical. Delay in bringing G-3 up to power quite possibly reflects the troubles that CEA had last year with G-2. Modifications made in the secondary cooling circuit of G-2 to eliminate hot spots in the prestressed concrete pressure vessel (NU, Jan. '60, 25) will undoubtedly be made also in G-3. "It's only logical," a CEA spokesman told NUCLEONICS, "that what we learned from G-2 will be applied to G-3 before we put it on the line."

And at Chinon, the state-owned public utility Electricité de France ran into difficulty welding up the 4-in. plates that make up the cylindrical pressure vessel for EDF-1 (NU, Dec. '59, 26). The method used, welding each ring-like section as it was put into place, resulted in residual stresses so high that one of the plates failed. The pressure vessel was dismantled and now a new approach is being used. This time the sections will be all put in place before any welds are made. The "preassembled" vessel will be covered temporarily with insulating material on the outside and heated from the inside to a uniform temperature of 400° F. The insulating material will be cut away at the joints only when the welds are made. In this way, EDF expects to get adequate control of heating and cooling during the welding operation and to hold residual stresses within acceptable limits.

The troubles with EDF-1's pressure vessel have set back its construction a year; the reactor is now slated to go critical late this year and on the line early in 1961. But the schedule for the other two Chinon reactors has not been changed. The 170-Mw(e) EDF-2, already under construction, will follow EDF-1 by a year. In mid-1964, EDF-3 will round out the installation (the three reactors fully tap the cooling water potential of the Loire at Chinon and no other reactors will be built there). Design characteristics of EDF-3 are not firm. The reactor will be a natural U, graphite-moderated gas-cooled type with capacity between 350- and 500-Mw(e). But after its experience with EDF-1, EDF may decide on a prestressed concrete pressure vessel for EDF-3.

New EDF Projects

In addition to the Chinon reactors, EDF has some other reasonably firm projects in its planning file. It has signed up, along with the Belgian Centre-Sud group, for a first-round 150 Mw reactor, in the Ardennes, under the U. S.-Euratom agreement (NU, Dec. '59, 20). EDF and its partners may opt for a second-round reactor at a Belgian site; otherwise EDF will probably go it alone for a second Euratom reactor. And in its domestic gas-cooled reactor program, EDF plans EDF-4 for mid-1966, with capacity of 400-Mw(e). There is some chance that it will be heavy-water moderated, but more likely EDF-4 will be the last of the graphite-gas reactors built in France.

If the schedule holds, France will be over the 1000-Mw(e) mark in nuclear generating capacity by mid-1966. But because of the tremendous potential of the Sahara oil fields, there is practically no chance for a massive reactor program in France until nuclear energy is competitive.

Army Food Program Cut Back Again; JCAE Unhappy

The Army Food Irradiation Program appeared to be on its way last month to a considerably reduced status—unless the Army has a change of heart on its own or under mounting Congressional pressure.

NUCLEONICS learned that only $500,000 has been budgeted for the program for the year beginning July (fiscal 1961), or one-fourth the current year's budget of $2-million. All $500,000 is budgeted for research; nothing for the new irradiation facility hoped for by the Army Quartermaster Corps (NU, Jan. '60, 27) to replace the cancelled Ionizing Radiation Center at Lathrop, Calif.

QM has proposed construction of a 1-million-curie cobalt-60 irradiator and a narrowing of the Army's effort to a few meats—beef, pork, poultry, etc. The proposal must be approved by Richard Morse, Army research and development director, who made the decision to cancel the proposed Lathrop center and who made it clear at Congressional hearings last month that he was against scheduling a new food irradiator.

Morse, AEC officials and others involved in the program were called to public hearings on the Lathrop cancellation by irate leaders of the Joint Committee on Atomic Energy. JCAE held two days of hearings; then, dissatisfied with and unappeased by Morse's reasons for dropping Lathrop, announced that further hearings would be held.

Rep. Melvin Price (D-Ill.), chairman of JCAE's research and development subcommittee, was particularly incensed over the situation. He attacked Morse on three counts: 1. cancellation of the center; 2. failure to send to JCAE a copy of an economic report on food irradiation prepared last summer by Arthur D. Little, Inc.; and 3. failure to give JCAE a report on biological problems which Morse had offered as another reason for dropping Lathrop (NU, Nov. '59, 26).

"This information should have been reported to the Joint Committee in advance," Price said in a statement after the two-day hearing, "so that its authenticity and credibility could have been checked."

Paradoxically, the debate over Morse's action does not involve the Lathrop center as it had been envisioned when Morse killed it. That project—a 24-Mev linear accelerator, a 2.2-million-curie cobalt-60 source and extensive pilot processing facilities—is dead, and few people are demanding that it be revived.

The real debate is whether the Army should proceed with a vigorous research-and-development program to perfect a relatively few irradiated foods and whether a large cobalt irradiator should be scheduled now in support of this narrower effort.

Massive Program Study Quietly Launched at AEC

AEC has quietly launched a program of potentially great significance —an intensive review of every one of its programs and long-range projection of each into the mid- or late 1960's. In ordering this massive appraisal, General Manager Alvin R. Luedecke has asked each of his divisions, in effect: "Where do you stand now and where are you going?"

The division responses—touching on virtually every conceivable aspect of a given program's scope—will, for the first time in AEC's history, give it the support material for long-range planning. The Reactor Development div. has done this on civilian reactor development (its so-called 10-year program to be made public this month) and this program will remain segregated from the rest of the Commission's over-all review.

Reports on all other programs are to be completed by August. At least two were complete or close to completion last month: the Isotope Development Program, the prototype for all other reviews under the program; and a review of equipment grants to educational institutions, which recommends to the Commission that grants be stopped after 1964. Sometime this month, three more reviews were expected to be finished: AEC contracting, nuclear fuel, and fuels processing.

Simultaneously with the program review, Leudecke has set his Budget Review Committee to work on a study of the annual budget cycle and the problems it presents to long-range planning. By August, when all of these efforts are concluded, AEC feels it will be in a position to: 1. streamline its administrative activities; and 2. act on a more realistic and effective basis in formulating policy, proposing legislation and preparing its budgets.

Radiation Gaging of Food Found Harmless at MIT

Samuel A. Goldblith, professor of food technology at Massachusetts Institute of Technology, has completed a study on the use of radiation gages by the food industry which appears to have headed off any possibility of a crisis for radiation like the cranberry scare of last fall.

Goldblith's study was commissioned by AEC's Office of Isotope Development at a cost of about $10,000. He found that volumetric gages used for process control in the food industry (liquid level gages, etc.) present no health hazard to consumers. His investigation was limited strictly to the gaging of food; it did not go into food treatment with radiation.

Radiation gages, he reported, induce no radioactivity; nor do they induce chemical changes until exposure periods go far beyond those used in processing control.

These questions arose after Congress revamped the federal food-additive law in 1958. Under the new law, radiation and hundreds of other additives had to be proved out on certain safety tests by March 1 of this year. Last June, AEC, with substantial spurring from the radiation-gage industry, asked Goldblith to compile the data necessary to comply with the law.

He has furnished his findings to the Food and Drug Administration well before the deadline, thereby averting, in the opinion of officials of both AEC and industry, a public challenge from FDA. In the case of cranberries, this was disastrous.

The first formal petition to FDA for clearance of radiation gages was made last month by Industrial Nucleonics, shortly after Goldblith completed his work.

Allis-Chalmers a Comer among Reactor Builders

In the spate of mergers that hit nucleonics companies last year, only one involved a pair of major reactor builders both of whom had power reactor construction contracts. That was the deal that saw Allis-Chalmers Manufacturing Co. of Milwaukee take over the assets, projects, personnel and good-will of the commercial nuclear operations of ACF Industries Inc. (NU, June '59, 31).

The merger brought under one management two of the country's four foremost exponents of the boiling-water reactor. It thus obviously went a long way to enrich and strengthen A-C's capability and to improve its competitive position.

Thus Allis, which got off to a slower start than most of the other reactor builders (including its two traditional competitors in the triumvirate of heavy electrical equipment manufacturers), is emerging as a formidable contender in the reactor stakes.

How to Consummate a Merger

It is of interest, therefore, to ask, nine months after the take-over of ACF's nuclear group: how has the merger been consummated? how is the resultant outfit organized? how is it working?

A-C's management philosophy has been to maintain the identity of the "Kennedy Street group" (where the ACF commercial nuclear unit had been—and still is located—in Washington, D. C.), and to integrate it bodily into A-C's existing organization, rather than breaking it up to swallow and digest it. (A cartoon displayed at Kennedy Street shows two animated letters "A" and "C" pushing out an "F.") Thus in the A-C Atomic Energy Division under vice-president Roy M. Casper, there are now three departments: Nuclear Power Department–Greendale (site of the new labs 20 minutes' drive from A-C headquarters in Milwaukee) under C. R. Braun; and Nuclear Power Department–Washington under Harold Etherington, still in charge as he was in ACF days. Third department is CSA—the fusion specialists under Leonard J. Linde who have joined with other fusion specialists from Radio Corp. of America in C Stellarator Associates, now building the C Stellerator for advanced fusion research at Princeton, N. J.

It was felt to be to A-C's advantage to keep the Washington group working together as a team, to permit it to finish a number of projects in progress: the Elk River, Minn., boiling water power reactor; the preliminary design of the Oak Ridge Experimental Gas Cooled Reactor; and five large testing-and-research reactors—M.I.T.; Wright-Patterson Air Force Base; Ispra, Italy; Petten, Netherlands; and Studsvik, Sweden.

A-C feels it has effected consolidation of this group into an Allis division, and has no plans to move the Etherington group elsewhere.

The two groups complement one another on people, skill and facilities—and on reactor types, what with Elk River being an indirect-cycle boiling reactor and Sioux Falls, Greendale's main project, direct-cycle boiling. Greendale and Washington may prepare proposals separately, or may act jointly. No restrictions are placed on the activities of either group: they are used as their skills dictate.

Broad Experience

Between them, A-C now has experience in both direct- and indirect-cycle boiling water, gas-cooled, fast breeder, large test-research and small training reactors—and fusion. Allis comes by its fast breeder experience as a charter member of both APDA and PRDC (Atomic Power Development Associates and Power Reactor Development Co., the Fermi Fast Breeder syndicates for research and for construction). In the training reactor field, Greendale has designed a 10-kw pool unit, and is now building one for the University of Maryland, to be ready for use by this fall.

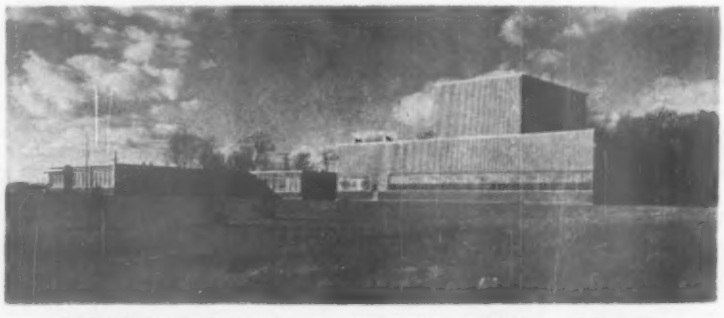
There are about 350 people in the Atomic Energy Division, 200 of them professional. Of the total, about 200 are in Washington, about 120 at Greendale, and ~30 make up half the CSA staff; of the professionals, 15–20% are physicists, 65–70% engineers. This high concentration is possible because for legal, financial, inspection and other housekeeping functions the division relies on the central Allis-Chalmers organization at West Allis near Milwaukee. Likewise, the division is supported by a much larger number of scientists and engineers in other A-C divisions, who are available and called on for work on heat exchangers, pumps, valves, turbines, etc. (The Greendale staff would have to be several times bigger, Casper says, but for this back-up experience.)

Moreover, the extensive manufacturing facilities at the vast West Allis works gives A-C the capability to fabricate all the parts of a nuclear power plant from pressure vessel to switchgear, with the exception of fuel elements. ("We have no plans now to get into fuel fabrication—there's ample capacity for present fuel needs.")

A Place in the Market

"The company made a decision, when it set up the Atomic Power department as a division in March 1957, to be in the nuclear power business," Casper recalls. "The acquisition of Washington was another step along the road.

"Power is our business, so we feel we are in this picture. We looked to see if there were a place in atomic power for Allis-Chalmers. [The company's first major venture, after supplying some nuclear components, was to design and build the power-generating equipment for EBWR, Argonne's Experimental Boiling Water Reactor, beginning in 1955.] We checked with our utility friends and found we were wanted



GREENDALE: Allis-Chalmers' new nuclear development labs near Milwaukee

in this business. We feel we are in on a good, sound basis—and we expect to make some money out of it."

Right now, Allis has a great deal staked on success of the 66-Mw(e) power reactor it is developing for Northern States Power Co. and ten associated utilities banded together as Central Utilities Atomic Power Associates (NU, March '57, R9; April '58, 22). Ground-breaking on the $28.8-million project is scheduled for this April near Sioux Falls, S. D. This was the first reactor project undertaken to embody integral nuclear superheat—the contract was signed in May 1957.

Inside Greendale

To carry out this pioneering project, A-C has a dozen development-and-test programs going on at its new nuclear development laboratory on 37 acres in Greendale, including:

- A 100-watt water-moderated critical assembly containing a duplicate of the Sioux Falls reactor core, including the superheat. Fuel for the boiler elements is being supplied by Sylcor, Mallinckrodt and American Lava, for the superheater elements by M&C Nuclear. Both regions use pellets: "We have no plans for metal—we believe in oxide."
- A loop to test, under reactor flow conditions of 60,000 gpm, a full-scale tangential steam separator.
- The underwater handling facility, a 40-ft high, 11-ft dia tank, similar in depth to the reactor vessel beneath the shield pool, in which underwater handling tools can be perfected, refueling techniques studied.
- What is claimed to be the world's most powerful heat-transfer test equipment.

Sioux Falls is a turnkey job, with Allis furnishing "everything but the site." The schedule calls for criticality in Summer of 1962.

The Washington group is closer to home with its Elk River project, scheduled to start loading fuel elements on November 1 this year, to reach criticality by Nov. 15, and full core loading by Dec. 15.

If relatively little has been heard until now about Allis' nuclear power work, it's due mainly to its basic philosophy of letting accomplishments speak first. "We should get enough results in the next year [1960] from our research and development program to see around the corner," declares Casper. "We will be out next year selling—and we will have enough results to convince people."

McKinney Setting Up Work of Panel

The foundations of U. S. international atomic policies and programs will be assessed by a one-man panel—Robert McKinney—for the Joint Committee on Atomic Energy, and the report is due by June 30. McKinney has formulated a beefy nine-part outline defining the subject matter he will cover.

McKinney's proposals were approved by Senator Clinton P. Anderson, JCAE chairman, on Nov. 17 and a working budget was roughed out. Since the budget is yet to be approved by the Senate, its total figure has not been announced, though it's estimated to be somewhere between $100,000 and the first McKinney panel budget of $60,000.

The study (NU, Nov. '59, 21; Dec., 20) will get help from both private research groups and educational institutions, in addition to the assistance already being furnished by JCAE, AEC and the State Dept. Other governmental agencies are being scouted to determine what assistance they might provide.

Invitations for research aid have been drawn up and will be turned over to JCAE, which will actually let the contracts.

Private industry has been asked to collaborate in the study through the Atomic Industrial Forum, which will act as a clearing house for information provided by industrial concerns. McKinney expects the industry to assist in estimating total amount of U. S. nuclear sales overseas vs. total U. S. expenditure in developing foreign markets.

Members of the citizens' panel of the 1956 study will have an opportunity to weigh the opinions and conclusions of the study before final publication.

This procedure apparently is a move to head off an attack by Walter Reuther, a former panelist, who is reportedly unhappy about having a one-man panel conducting the survey. Word is that Reuther, always a staunch supporter of the Euratom program, is fearful how Euratom may weather the study. McKinney has not hesitated in the past to declare that the joint U. S.-Euratom power program "won't go."

Oil, Gas and Coal

McKinney's report will devote a good deal of emphasis to long-range world energy requirements. The competition between fossil fuels and atomic energy in meeting these requirements will be a prominent part of the study. Interior Dept. will handle this, for the most part.

More attention will be paid to the exact economic aspects of fossil fuels, and in particular to fuel oil. Staffers plan to check with operating utilities on the efficiency of fuel oil complexes, having heard that some utilities are quite dissatisfied with fuel-oil costs.

AKS out; Euratom program totters, though Givet firm

The Joint U. S.–Euratom power-reactor program reeled last month from what may well prove its deathblow—the reported withdrawal of the Stuttgart AKS group from its planned 150-Mw(e) organic-moderated reactor station. The bad news came even as the Franco-Belgian group filed firm assurance on its Givet project.

1. AKS told Euratom Jan. 16 that they were "not in a position to give definite assurance" they would build. Reasons, not stated, were presumed to relate to improved costs of fossil power in Europe. Bonn's $24-million guarantee on losses stands. AKS was reported proposing a smaller organic plant, but they would not be covered by the existing U. S.–Euratom pact.

2. Electricité de France and its Belgian partners filed a binding undertaking to build the CNA reactor at Givet. They have narrowed down prospective manufactures from four (NU, Dec. '59, 20) to two: Framatome (Westinghouse) and General Electric.

3. There was mounting recognition in both Brussels and Washington of changed European conditions. AEC staff was preparing a substitute program centered on research-development and prototype-plant-building, with guarantees to SENN and CNA. U. S.–Euratom talks were expected shortly on measures to shore up the sagging bloc—possibly in cooperation with Canada.

3 Generations of Gas Reactors for Ships Underway at GA

Just two years ago General Atomic division of General Dynamics Corp. was awarded a joint AEC-Maritime Administration project to develop a high-temperature gas-cooled reactor with closed-cycle gas-turbine propulsion plant for merchant ship use, and to build a land-based prototype in five to seven years (NU, Feb. '58, 24). Now, after only two years of work, GA is already confidently looking two steps beyond the prototype.

The firm has roughed out parameters for a first shipboard application of its Maritime Gas-Cooled Reactor, which for planning purposes it calls Mark I, and is already thinking about a still-further-improved hypothetical Mark II MGCR, a decade away.

Closer to home, GA is planning to start construction at once of a critical experiment to prepare for the prototype. This will be built in the original Triga critical facility at GA's John Jay Hopkins Laboratory at San Diego, Calif., for start-up in July. It may be a "driven critical," with one-third of the MGCR core mocked up and driven with a two-thirds graphite critical assembly. A succeeding step would replace the graphite with beryllium oxide and result in a complete BeO critical. Results of the critical program will yield a check on analytical methods and normalization of design calculations.

Construction of the full-scale prototype is scheduled to begin in late 1961, subject to final governmental approval. It is to be completed and in operation early in 1964. The site has not yet been selected.

Meanwhile a staff of 85 scientists, engineers and technicians at GA (not counting 40 more at a sister division in General Dynamics, Electric Boat, nor those at Westinghouse, subcontractor for the turbomachinery) are busy trying to wed together two advanced systems—the gas-cooled reactor and the closed-cycle gas turbine. The MGCR system holds out promise of attaining higher temperatures and of using them more efficiently; and, by doing away with the steam cycle, of achieving a simple, compact and lightweight power plant.

The MGCR development program has been built around the unique problems encountered in the nuclear closed-cycle gas-turbine system, with emphasis on the system's high temperatures and novel working fluid. First such problem was the selection of moderator and a compatible coolant. The moderator was originally scheduled to be graphite, but recent advance in the technology of beryllium oxide combined with a substantial reduction in its cost now favor beryllium oxide because of its high neutron economy with corresponding improvements in fuel costs. The reflector will be either graphite or BeO. Helium is the obvious choice as working fluid because of its inertness, its efficiency as a heat transfer medium and the low pressure losses throughout the system it entails.

The future development program includes:

1. Methods of fabricating BeO structural shapes and determination of their physical properties under reactor conditions; 2. Reactor vessel and non-frangible insulation designed to permit use of low-alloy steel pressure vessels and piping; 3. Tests of engineering materials exposed to a high-temperature helium atmosphere; 4. Control rod drive mechanisms capable of operating in the hot helium reactor environment and withstanding shipboard accelerations and vibrations; 5. Turbomachinery for use with helium working fluid, including aerodynamic and mechanical design of compressors and turbines, and special shaft seals.

One of the principal operational advantages of the MGCR cycle is its ability to maintain an almost constant high efficiency over a wide range of power levels. Unlike steam cycles, which do not begin to approach 28–30% efficiency until 70% of full load shaft horsepower, an MGCR system can operate at its 37% cycle efficiency throughout a range from 10% to 100% of full load. This is important on board ship where operation at partial-power conditions may be required for extended periods, as during a storm or in confined waters. Likewise, extreme flexibility of operation is a characteristic of closed-cycle gas turbines, which can vary output power from full-power to zero or vice versa in a matter of seconds.

On economics, the Mark I MGCR with its 37% efficiency is expected to be competitive with then-current oil-fired ships. Space saving is more than ½ over a *Savannah*-type reactor. The Mark II design, described as a "rational extrapolation" of current technology in materials and turbomachinery, and benefiting from anticipated advances in gas turbine design, techniques and materials, as well as operating experience with Mark I, is estimated to achieve 40% efficiency. Based also on 30,000 shp but attaining 1700° F reactor-outlet temperature, its weight in lb/shp will be comparable to conventional powerplants if fuel weight is not included, and will be much lighter if fuel weight "for any reasonable trip" is included.

The First Two Generations Compared

	Prototype	*Mark I*
Shaft horsepower	22,750	30,000
Output, Mw(th)	53	62
Basic cycle efficiency, %	32	37
Coolant temp. at reactor inlet, °F	753	881
Coolant temp. at reactor outlet, °F	1300 (max. 1500)	1500
Maximum operating pressure, psig	800	1200
Reactor vessel inside dia, ft	9.67	9.67
Reactor vessel inside length, ft	17	17
Reactor vessel construction material	Mn–½ Mo steel	Mn–½ Mo steel
No. of fuel assemblies	292	292
No. of control elements	16	24
Core dia, ft	6.4	6.4
Core length, ft	6.4	6.4
Reflector material	C or BeO	C or BeO
Moderator material	BeO	BeO
Burnup, Mwd/ton	24,000	24,000
Turbine inlet pressure, psi	778	1,123
Turbine over-all length, ft	32	32
Tanker size equivalent, deadwt. tons	37,500	60,000
Earliest availability	1964	1967

Reactor News

DRESDEN ROD DRIVES FIXED, RELOADING NEAR

"Refinements" on Dresden's control rod drives were completed as of Jan. 20 (after all 80 underwent 500 scrams). The station staff hoped to start reloading in time to resume critical testing by month's end.

PG&E PASSES HUMBOLDT HURDLE

Pacific Gas & Electric, which hopes to start construction of its Humboldt Bay boiling-water reactor plant this spring, cleared a significant hurdle last month when the California Public Utilities Commission granted a certificate of convenience for the project. The $21-million plant (NU, March '58, 17; June '58, 25) will be Unit No. 3 at Humboldt Bay station, 285 mi north of San Francisco, where there are already two fossil-fired plants with a gross capacity of 100 Mw. The reactor plant will add 60–70 Mw, delivering steam at 1,000 psi, 550° F to a 3,600-rpm tandem-compound turbine connected to a 70,588-kva generator. The core will contain 30,500-lb 2%-enriched UO_2. . . . Meanwhile PG&E bought a 160-acre tract at the south end of Bodega Head, 35 mi north of San Francisco, for the 200+-Mw plant it will build for 1965 completion. This will be a nuclear plant if 6.5-mills/kwh power can be attained (NU, June, '59, 28).

S1C AT FULL POWER

Combustion Engineering's S1C submarine reactor prototype at Windsor, Conn., reached full power Dec. 19. A pilot version of the S2C that will power the hunter-killer sub *Tullibee*, to be launched at Electric Boat this spring,

S1C first went critical back in August, but developed an operating variance from predicted calculations: higher coolant-water pressure in the second pass. Although this was only 1% greater than called for, it was feared a cluster might have been blocked and might lead to a meltdown; the core was taken apart, found in good order, reassembled, and the reactor runs well—still with 1% less pressure drop; the flow-rate is satisfactory.

NBS COMPLETES ITS REACTOR DESIGN

Conceptual design of a heavy-water, high-flux research reactor has been completed by the National Bureau of Standards' reactor group (NU, Aug. '58, 25). A modified version of Argonne's CP-5, the design has these innovations: 1. splitting of fuel elements into two active zones with a solid aluminum central section next to the neutron beam ports, for better radiation protection; 2. a special fuel assembly with fully-enriched-U walls making it impervious to slow neutrons, and creating a fast-neutron chamber within for solid-state research; and 3. a "cold neutron" (subthermal) facility in the core coolant channel, where a small volume is cooled by cryogenics to 30–40° Kelvin, for solid-state studies.

LONG BEACH COST QUERIED; NAVY NEWS

Another Rickover-vs-industry scrap seemed ready to explode at Quincy, Mass., where cost of the nuclear cruiser *Long Beach* was at issue. A naval spokesman in Washington said her cost would rise from $87- to $250–300-million. However, NUCLEONICS learned, the latter figure includes cost of propulsion plant and armaments, the former does not. Moreover, Bethlehem Shipbuilding Co.'s Quincy yard (where *Long Beach* is now fitting out) feels it is going to finish the job within its original cost estimates. A Rickover cost-investigating committee was followed at Quincy by one sent by Navy boss Admiral Burke. . . . Westinghouse got a contract for two more S5W reactors for *Thresher*-type attack subs in the 1960 building program. The $13,824,000 contract includes $12,425,000 for reactor vessels, control drive mechanisms, main cooling systems including steam generators, pumps and main loop piping; remainder is for design work. . . . Commissioning of the Regulus guided-missile-firing A-sub *Halibut* Jan. 4 brings to three the number of nuclear submarines operating with the Pacific Fleet (with *Sargo, Swordfish*). During her trials, a valve malfunction threw *Halibut* into a 60° downward dive; the crew quickly stopped the dive and backed the sub out to a normal plane. The power plant was neither involved nor affected. . . . *George Washington*, first Polaris ballistic-missile-firing sub, was commissioned Dec. 30, a spectacular 26 months after keel-laying.

HANFORD FUEL ELEMENT BURSTS, NO DAMAGE

Rupture of a fuel element in a reactor at the Hanford plutonium works on Dec. 21 resulted in sparse ground contamination in a small section of desert land inside the atomic reservation when some active particles escaped boundary, according to officials of General Electric, operators of the plant for AEC. Employees leaving the area got special shoe checks for 48 hours but no contamination was discovered. GE told NUCLEONICS such ruptures are considered routine at Hanford, and that minor releases of activity occur perhaps once or twice a year. The reactor was shut down, but GE said the length of time was classified defense information.

AI COMPLETES LARGE HOT CELL

"Largest privately-owned facility in the world for remote examination of radioactive materials" is Atomics International's claim for its Components Development Hot Cell being completed at its Santa Susana reactor center.

REACTOR FUEL CONTRACTS AWARDED

Martin has obtained the $390,000 contract to produce the UO_2–ThO_2 fuel elements for the **Elk River** reactor. The contract covers 148 bundles, each of 25 five-foot stainless steel tubes filled with pellets of the mixture of uranium and thorium oxides; and 22 extra bundles spiked with additional U^{235} for supplementary loading. The core will contain 480 lb UO_2 and 5 tons ThO_2. The steel tubes will contain boron as burnable poison. The order is to be completed by fall; Elk River is slated to go critical in November. . . . **Mallinckrodt** Nuclear Corp. will produce the fully-enriched uranium Westinghouse will fabricate into fuel elements for Britain's first nuclear submarine, HMS *Dreadnought*. Mallinckrodt is also supplying 14,175 lb 3.9%-enriched UO_2 in powder form—$3-million worth—to General Electric to be fabricated into the second core for NS *Savannah* (NU, May '58, 27). Mallinckrodt has completed shipment of more than 20,000 lb of 4+%-enriched UO_2 that Babcock & Wilcox is making into *Savannah's* first core. . . . B&W also has obtained a contract to supply the third core for the **Battelle** pool reactor: 27 fuel and 6 control elements.

World News

USSR Has 3 A-Subs ?

The Red Fleet of Soviet Russia has three nuclear submarines under construction, according to the authoritative British annual *Jane's Fighting Ships*. "One atomic powered submarine is nearing completion, another is in an advanced stage of construction, and a third is being assembled," *Jane's* new edition says. Characteristics are given as 3,000 tons displacement, 328 ft length, 33 ft beam, 20 ft draft, 14,000 shp, 25 knots (compare with U. S. A-subs, NU, Sept. '59, 74). It's also stated that in addition to this large long-range sub, two other types reported under construction are an attack type and a radar picket type, "one or both of which will be nuclear."

SELNI Site Picked

Italy's SELNI group will build its Westinghouse reactor plant (NU, Dec. '59, 26) on the Ligurian coast 1½ mi west of Moneglia, about equidistant between Genoa and La Spezia. The site is on a small gorge facing the sea, where the plant will be surrounded by mountains protecting even the closest towns. The choice must be approved by the Ministry of Industry.

Incident at Japan's JRR-1

Japanese Research Reactor No. 1, a 50-kw Atomics International solution type, suspended operation following a minor accident Dec. 8 that "filled the interior of the reactor section with radioactivity." However, "we are positive it was completely contained within the section," a scientist at Tokai Mura said.

Reactors Critical in Britain, Yugoslavia

The fourth and last reactor at Chapel Cross, Scotland, went critical Dec. 29; it is expected to go to power in three months (NU, Jan. '60, 23). . . . Yugoslavia's first large research reactor, supplied by Russia, was put in operation Dec. 28 by President Tito at the Boris Kidrich Nuclear Institute at Vinca near Belgrade. The unit is identical to one sold by Russia to Red China (NU, Jan. '59, 21). A critical facility, in operation for some time, figured in a recent accident (NU, Dec. '59, 26).

Hunterston Construction Resumed

Work on Hunterston Nuclear Power Station was resumed last month following labor-management negotiations, 16 weeks after 500 workers were suspended by Motherwell Bridge & Engineering Co. for "persistent misconduct." There had been 32 strikes in 18 months and work was running 15 months behind schedule.

OEEC Liability Convention Advancing

OEEC's third-party liability convention moved closer to ratification early last month when its drafters resubmitted it for approval to the European Nuclear Energy Agency steering committee after adding a provision for state intervention in accidents where damages exceed the operator's liability limit. The provision does not establishing a fixed ceiling for government indemnification of damages above the $15-million maximum operator's liability limit, but instead calls for reciprocal government indemnity agreements between neighboring countries. This formula gives individual governments the means to protect their citizens against catastrophes in other countries as well as against domestic accidents. France, major objector to the previous draft, will probably be satisfied; she apparently intends to provide $35-million indemnity above the $15-million limit, and possibly another $50-million, in her own indemnity legislation. ENEA's steering committee was expected to pass the convention to the OEEC Council late in January, with the prospects for approval good and the five ratifications then needed to put it in force hoped for this year.

U. N. Completes 32-Volume Geneva Record

What must surely be one of the most massive achievements in the history of collating and disseminating scientific information was concluded when the United Nations published the 32nd volume of the proceedings in English of the Second Geneva Conference of 1958. (A 33rd index volume is all that remains to be published.) The compilation of more than 2,100 papers from 46 countries was carried out, edited and printed within 15 months after the end of the conference. Also published by U. N.: 13-volume abridgments of the conference record in French and in Spanish. As in the case of the first, 1955 Geneva Conference, after which the "Geneva volumes" long remained the ultimate reference authority, the new set provides a complete encyclopedia of the state of the atomic art as of September 1958.

GEC Sets Up Subsidiary for Japanese Job

The British General Electric Co. of Japan was set up by GEC shortly after it had signed a $56-million contract with the Japan Atomic Power Co. to build a 159-Mw(e) Calder-type reactor plant at Tokai Mura. The new company will cover 50 British engineers and technicians GEC will send to Japan. Total cost of the reactor, to be completed in 1964, will be $86-million.

U. N. Favors Third Geneva Conference

U. N. Secretary-General Dag Hammarskjold reported to the General Assembly that the U. N. Scientific Advisory Committee was unanimous as to the desirability of holding a third international conference on peaceful uses of atomic energy under U. N. sponsorship, that Geneva would again be the most likely site, and that 1962 "would seem a desirable year in which to hold" it. However his own report said it would be premature to "present any firm conclusions" about a third conference—"more study and consultation are needed."

British Consortia's Merger Effected

The Nuclear Power Group, TNPG for short, is the name of the new organization formed by merger of Britain's Nuclear Power Plant Co. and the AEI–John Thompson Nuclear Energy Co. (NU, Oct. '59, 24). The two groups are "partners on an equal basis in all respects," but observers felt the predominant NPPC members were likely to get the preponderant share of subcontract work. TNPG now has three projects: Bradwell (300 Mw), Berkeley (275), and Latina (200).

Belgium's BR-2 Goes Critical

BR-2, the big high-flux testing reactor at Belgium's Mol nuclear center went critical Jan. 14.

CERN: Synchrotron Working; Ford Gift

The world's biggest accelerator, the 25-Bev CERN proton synchrotron near Geneva, is now in operation after a six-year building effort by the twelve member nations of CERN (European Organization for Nuclear Research). (Brookhaven National Laboratory is nearing completion of its 25-Bev synchrotron.) . . . CERN last month approved a $15-million budget for 1960, and was beneficiary of a four-year, $500,000 grant from the Ford Foundation to bring physicists from non-member countries to the CERN labs.

News in Brief

Enriched U: Thor-Westcliffe and AEC

Officials of Thor-Westcliffe said last month that the firm was hoping for a construction start this spring on its developmental cascade system for producing enriched uranium (NU, Oct. '59, 17). An AEC permit for import and storage of seven machines from West Germany was expected before the end of January; construction cannot start, however, until AEC issues a construction permit, after review of the hazards' situation. Meanwhile, the firm had not decided whether to accept AEC's offer of a no-cost contract for an exchange of unclassified information on gas-centrifuge technology. AEC has a program at the University of Virginia (classified and unclassified) with an annual budget of about $300,000 a year; also, AEC has asked General Electric to analyze both the economics and technology of gas centrifuging to provide an up-to-date picture of the process's importance.

Weinberg Comments on National Lab Issue

Alvin M. Weinberg, director of the Oak Ridge National Laboratory, has jumped into the controversy over the role of the national laboratories (NU, Dec. '59, 19). In his annual "State of the Laboratory" address to ORNL employees he declared: "Simple prudence dictates that the government, having spent so much money on these institutions, should get its money's worth out of them by having them do what they were first set up to do. Their work can pave the way for the establishment of bona fide, large-scale nuclear enterprise."

U. S. Awaits Word on Russian Exchange

AEC officials said last month that the next step in exchange of scientists and information with the Soviet Union (NU, Dec. '59, 24) was a proposal from Russia's nuclear boss, Vasily Emelyanov, on specific exchange details. The Emelyanov proposal was expected by the end of January.

McCune Promoted, Perhaps Out of Atomic Field

General Electric Vice President Frank McCune was promoted—perhaps out of atomic energy—to VP, Engineering Services, for all GE. But he will fill out his term as Atomic Industrial Forum head, and carry on "certain continuing assignments," presumably atomic.

AEC Task Force Prepares Federal-State Paper

An AEC task force has completed the first draft of criteria under which AEC would transfer regulatory responsibility over certain nuclear activities to competent state governments (NU, Oct. '59, 21). The next steps—in roughly this order, according to AEC officials—will be: review of the proposed criteria by the four-man Commission; circulation to interested government agencies for comment; circulation as a proposal for comments of state and local bodies; and adoption as final. AEC's Health and Safety Office has given top priority to the transfer program but the criteria schedule indicates that any actual transfer is some time off.

AEC Changing Lease Form on Fissionable Material

A new leasing agreement for special nuclear material is to be put into effect by AEC at the end of this month. It covers all fissionable material received by Commission licensees after Feb. 29. At the same time, AEC has centralized administration of leasing functions of fissionable material in the Oak Ridge Operations Office. The terms and conditions for all leasing transactions will be spelled out in a single agreement with each licensee. All such agreements will expire June 30, 1963—to permit "a reasonably early re-evaluation" of AEC's entire program for fissionable materials.

3-Firm Group Offers to Build Test Reactor for AEC

A three-company partnership—Allis-Chalmers, Republic Aviation and Minnesota Mining & Manufacturing—has offered to build the advanced test reactor AEC says it needs for the naval reactor and other program (NU, Jan. '60, 26). Industry sources said the group was willing, with its own funds, to build: 1. a reactor of its own design "tailored to meet AEC's high-flux requirements"; or 2. a reactor of AEC design (Phillips Petroleum has prepared a conceptual design for AEC). AEC is on record in favor of encouraging private ownership of test reactors —with the help of long-term AEC contracts—but has not yet committed itself. However, it has asked $24-million from Congress should an arrangement for private construction fail to develop.

News Notes: India, Washington, Ohio, JCAE

Vitro International has been awarded a contract by the Indian government for design of a $4-million **high-level radiation laboratory** to be built at the Trombay nuclear center; a special feature would be hot-cell areas for experiment with plutonium and other toxic materials. . . . **Potomac Electric Power Co.**, Washington, D. C., has joined High Temperature Reactor Development Associates, co-sponsor of the gas-cooled reactor to be built by Philadelphia Electric. . . . Ohio Governor Michael V. DiSalle has named the nine members of the State's **Atomic Energy Advisory Committee,** including William Eells, former atomic energy coordinator in Ohio; the committee will advise the State's new Department of Industrial and Economic Development. . . . **The Joint Committee on Atomic Energy** has scheduled its annual "202" hearings (state of the atom) for Feb. 16–19 and 23–25. Other hearing dates: AEC's construction authorization program for fiscal year 1961, March 8–10 and Apr. 5–7; Frontiers of Atomic Energy (NU, Jan. '60, 18), March 22–24; Radiation Standards, late April or May.

New York Utilities Organize, Studying A-Power

Formation of Empire State Utilities Power Resources Association (ESUPRA) was announced by New York State's seven major utilities—Con Edison, Central Hudson Gas & Electric, Long Island Lighting, N. Y. State Electric & Gas, Niagara Mohawk, Orange & Rockland Utilities, and Rochester Gas & Electric. "A continuing evaluation of nuclear power" is a key project, directed by John E. Dunning, dean of engineering, Columbia Univ. The State's Atomic Development Office wants ESUPRA to sponsor a big reactor for 1965 completion, but some in the group would like to see Indian Point results.

Silverman Succeeds McCullough at ACRS

Leslie Silverman of the Harvard Univ. School of Public Health has moved up to succeed Rogers McCullough, Monsanto Chemical Co., as chairman of the AEC Advisory Committee on Reactor Safeguards. McCullough had been chairman since 1957 but had just completed his first formal term (a one-year term was established a year ago). Silverman's term expires Dec. 31. McCullough continues as an ACRS member and will stay on in Washington for a few months to help Silverman.

Radiation News

Georgia Tech Installs Large Cesium Source

The free world's largest cesium-137 radiation source—12,000 curies—was installed last month at Georgia Tech, one of five research centers supported by AEC's Office of Isotope Development. The source will be used initially for research on kaolin, breaking down the material's crystals in an attempt to produce a high-quality clay. It will also be available for other industrially-oriented radiation studies. The cesium was encapsulated by Oak Ridge National Laboratory and installed in a 12-foot well under Tech's new Radioisotopes and Bio-engineering Laboratory. The 12 capsules—of about 1,000 curies each—are arranged in a circular bundle one foot in diameter.

ENEA Studying Mobile Food-Irradiation Program

The European Nuclear Energy Agency (NU, July, '59, 22) has roughed out a proposal for mobile radiation sources that would visit agricultural and food-research centers in Europe for pilot-plant studies of food irradiation. Preliminarily, the proposal calls for two or three mobile cobalt-60 units, each between 20,000 and 30,000 curies. The sources would be mounted on shielded trucks equipped to insert and extract the sources at local conveyor facilities. Estimated cost of three mobile units and a home base is $1–2-million.

Most promising applications, ENEA officials feel, are low-dose treatments to extend shelf-life of fruits and high-protein foods, prevent potato sprouting and control food-borne diseases such as salmonellosis, the dried-egg disease. At this point, sterilization of food is not under consideration; all attention would go to low-dose treatment, under local processing conditions, in large enough quantities to get commercial-type information.

ENEA expects to establish a study group that would report in early summer on how to deal with major problems. These include financing (split the cost between government and industry?), administration (home base for the mobile units would probably be a major agricultural or food-research center), and legal questions (transport is a problem). The group will also draw up cost and technical specifications.

RAI, Tensolite Set Up Radiation Subsidiary

Radiation Applications, Inc., New York, and the Tensolite Insulated Wire subsidiary of Carlisle Corp., Tarrytown, N. Y., have established a subsidiary to produce irradiated-polyethylene wire and cable. The joint venture, Irradiated Insulations, Inc., is expected to go into production about April 1; it will also develop new insulating materials. General Electric, High Voltage Engineering Corp. and Radiation Dynamics were competing to supply a radiation machine to the new firm and GE won. All machines currently employed for irradiation of polyethylene are GE resonant transformers.

Victoreen Supplying Radiation System for Hallam

Atomics International has ordered a radiation detection system from Victoreen Instrument Co. for the sodium-graphite power reactor under construction at Hallam, Neb. The system will monitor areas within the plant, vapor vents, effluent gases released to the building stack, and sewage leaving the plant.

AEC Gives 4 New Isotope Contracts, Renews 6 Others

Ten contracts, totalling $447,834, have been awarded by AEC under its Isotope Development Program. Six are extensions of previous contracts; four are new. Two of the four new contracts reflect the program's new emphasis on "public interest" projects, supplementing industrial-type work (NU, Nov. '59, 32). New contracts:

U. S. Bureau of Mines. Explore use of tracers for fluid dynamic studies, $15,000.

Isotopes, Inc.: Use of isotope technology in the water-resource field, $42,200.

Jarrell-Ash Co.: Feasibility of using beta rays to generate x-rays suitable for flourescent spectroscopy, $32,600.

Texas A & M: Established as the fifth research center for isotopes, $50,000 (first year). The other centers are Georgia Tech (*see above*), MIT, Chicago Univ. and Research Triangle Institute, N. C.

Extended contracts:

W. H. Johnston Laboratories: Basic radiation technology studies, including use of the coincidence mass spectrometer for study of multiple ionization processes, $84,600.

Radiation Applications: Foam separation techniques for fission-product separation and concentration, $36,000.

Battelle: Tracers for process and quality control, $49,600.

Library of Congress: Monitor world literature on industrial isotope applications, $30,734.

Textile Research Center: Modification of fiber by radiation induced in situ polymerization of monomers; also development of activation analysis techniques for textiles, $67,600.

Tracerlab. Radiochemical methods for detecting and analyzing non-radioactive gases, $39,500.

Military Establishing Radiation Research Center

The Defense Dept. plans to establish a radiation research center at the National Naval Medical Center, Bethesda, Md. Although it will be built primarily for weapons-program lab work, it will also be available to all government agencies for study of such things as reactor shielding, medical uses of radiation, and advanced training in health physics and radiobiology.

Developments at Budd, Curtis

Budd Co. has merged its Nuclear Systems and Tatnall Measuring Systems division into the Instruments div., headed by John H. Buck; main office will be in Phoenixville, Pa. . . . Budd has also created a SpaceAtomics div., formerly Defense div.; in the nucleonics field, SpaceAtomics will supply components and instrumentation to the reactor industry. . . . **Curtis Nuclear Corp.**, a new firm in Gardena, Calif., has purchased the nuclear medical instrumentation operation of American Electronics, Culver City, Calif.

Budd Ships 10,000 Curie Co Source to France

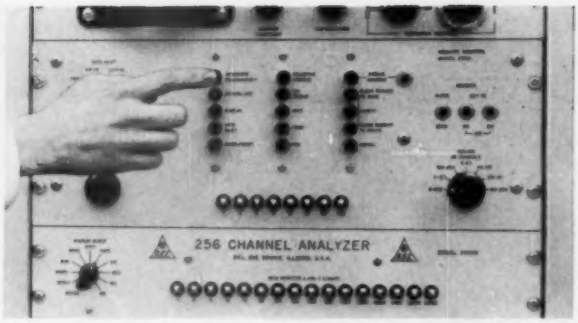
Budd Co. (*see above*) also completed its largest overseas shipment of radioisotopes last month when it delivered a 10,000-curie cobalt-60 source to the French Atomic Energy Commission. The source—ten stainless steel pencils containing 50 wafers each of Co^{60}—will be used for radiation physics and chemistry research at the Commission's Nuclear Research Center, Saclay.

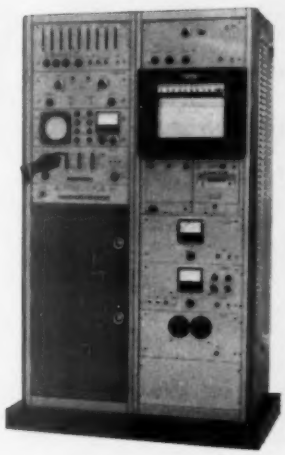
USPHS Establishes Radiation Reporting, Plans 3 Labs

The U. S. Public Health Service will begin publication of a monthly report on environmental radiation March 1. The information will be developed from federal, state and private sources (NU, Sept. '59, 21). USPHS has also decided to establish radiation laboratories at Las Vegas, Nev., Montgomery, Ala., and Rockville, Md.

NEW RCL 256 CHANNEL ANALYZER

with pre-selected automatic programming lets you concentrate on research instead of analyzer operation





New Model 20613 retains familiar appearance and functional design.

The desired analyzer cycle, including any or all of 12 separate operations, can be pre-programmed on the easy-to-operate programming patchboard. Then, at the touch of a single button the analyzer automatically performs the specified operations, thus freeing you for other work. For example: Data can be accumulated; stored background substracted, and data read out without manual intervention.

Automatically programmed operations include: Accumulate . . . Display . . . Strip Chart Recorder . . . Digital Printer . . . Log Converter . . . Data Shift . . . Complement . . . Test . . . Selective Storage . . . and all Re-Set Functions.

Single Push Button Manual Operation—To further simplify operating procedures all front panel lever switches have been replaced with push buttons. Now, all normal operations can be performed by pressing a single button.

600-2500 High Voltage Power Supply—Positive or negative at 5 ma. Line Regulation: ±10% line change yields ±0.02% load change between 600 V—1800 V and ±0.03% load change from 1800 V to 2500 V.

Readout—Six modes of readout are available: digital printer, strip chart recorder, X-Y plotter, punched paper tape, magnetic tape and CRT display.

MAGNETIC TAPE AUXILIARY MEMORY ALSO AVAILABLE

The entire memory content can be recorded on magnetic tape within 10 seconds and later "played back" into the memory for re-use. All or any fraction of the counts in each channel may be added to or subtracted from data accumulated in other studies.

RCL RADIATION COUNTER LABORATORIES INC.

5121 West Grove • Skokie, Illinois • U.S.A. • ORchard 3-8700

TRANSISTORIZED RCL 256

Available June 1st

RCL, the most experienced designer and manufacturer of transistorized multi-channel analyzers, is proud to announce the development of the most advanced analyzer on the market today—the new, transistorized RCL 256 Channel Scaler-Analyzer with digital number and curve CRT display.

Transistorized RCL 256 features Data Shift . . . Log and Linear Display . . . Selective Storage . . . Plug-in Modular Construction . . . Dimensions: 21" high x 19" wide x 24" deep.

For complete specifications and firm delivery date write RCL, Dept. 120.

It's triplets at General Mills!

Three new models! Now a family of six <u>standard</u> Mechanical Arms

General Mills is proud to announce the addition of three new standard mechanical arms that will serve a wide range of remote handling applications. These three, described at right, added to our present line mean that in most cases General Mills can solve your remote handling problems without expensive custom engineering.

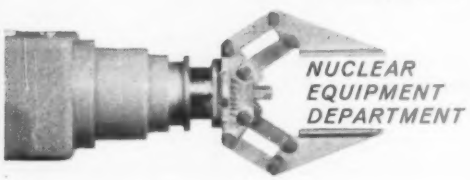
So if you are planning an operation involving remote handling, consult the Nuclear Equipment Department of General Mills early in the design stage. Many times, with only minor alterations, we can adapt a standard mechanical arm to your particular installation. Chances are that with our "know-how," gained from wide experience in the field, we will be able to offer other cost-cutting suggestions, too. *Free Booklets* give details on the new arrivals. **Write:**

Nuclear Equipment Department
Mechanical Division of General Mills
419 North Fifth Street
Minneapolis 1, Minnesota

Model 100 Manipulator. Designed for use in the smaller hot cells found in industrial and university laboratories as well as the larger AEC installations. Provides high load capability, 200 pound vertical lift, full cell coverage, and manipulating versatility *at low cost*. Fingertip controls are mounted in easily portable control box. The Model 100 comes as a complete system ready for installation.

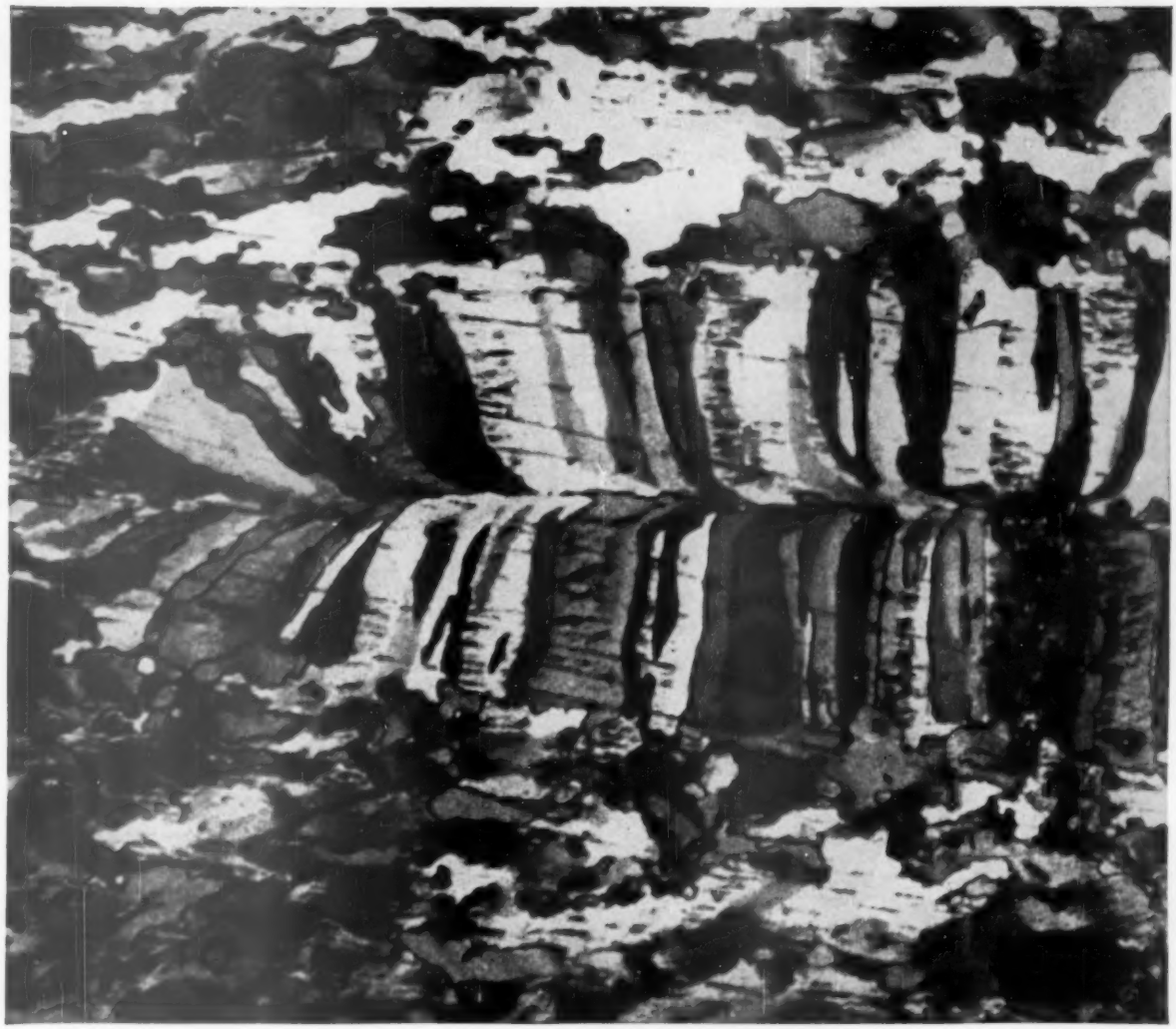
Model 150 Manipulator. Primarily designed for use in alpha-gamma operations where a maximum of manipulating versatility is required in a minimum of space. The drives are all electrical. All speeds are infinitely variable from fingertip control station.

Model 550 Manipulator. Designed for great versatility, heavy load applications. With a compact structure it handles 100 pounds cantilevered at 18 ft. and proportionally higher loads as the moment is reduced. Infinitely variable speeds are regulated from a portable control box.



First In Remote Handling
MECHANICAL DIVISION
Minneapolis, Minnesota

General Mills



BERYLLIUM: successful resistance weld!

This photomicrograph is visual proof that beryllium can be resistance welded. Extensive tests at the Budd Company indicate useful sheet metal products can be fabricated from beryllium. Work with beryllium at Budd includes successful hot rolling, brake forming, deep drawing, brazing, resistance welding, arc spot welding, arc welding, cleaning, machining and hot shearing.

Creating structures—thru the use of promising new metals and alloys—and making these concepts practical realities has been a Budd specialty for 30 years. Write today for further information. The Budd Company, Philadelphia 32, Pa.

SPACEATOMICS Budd DIVISION

atomic progress

THROUGH

58 YEARS

pioneer

SERVICE

&

ENGINEERING CO.

231 S. La Salle Street,
Chicago, Illinois

In 1952 Pioneer joined with other groups, all reporting to the Atomic Energy Commission, for constant study of atomic energy application. Today Pioneer is qualified as a consultant to industry in the application of atomic reactor systems to the generation of electric power. Presently, Pioneer is acting as architect-engineer and supervisor of construction of the 66,000 kw commercial atomic power plant shown here. Allis-Chalmers Mfg. Co. is the prime contractor. Scheduled for 1962 completion, the plant, for the Northern States Power Co., will be known as the "Pathfinder".

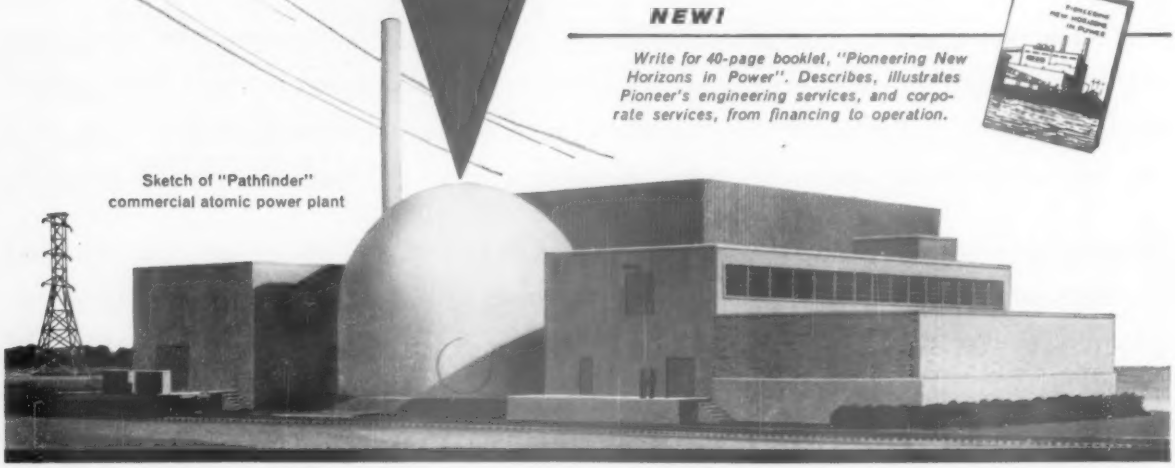
Organized as Central Utilities Atomic Power Associates, these utilities will share in the research and development costs: Northern States Power Co., Central Electric and Gas Co., Interstate Power Co., Iowa Power and Light Co., Iowa Southern Utilities Co., Madison Gas and Electric Co., Mississippi Valley Public Service Co., Northwestern Public Service Co., Ottertail Power Co., St. Joseph Light and Power Co., Wisconsin Public Service Corp.

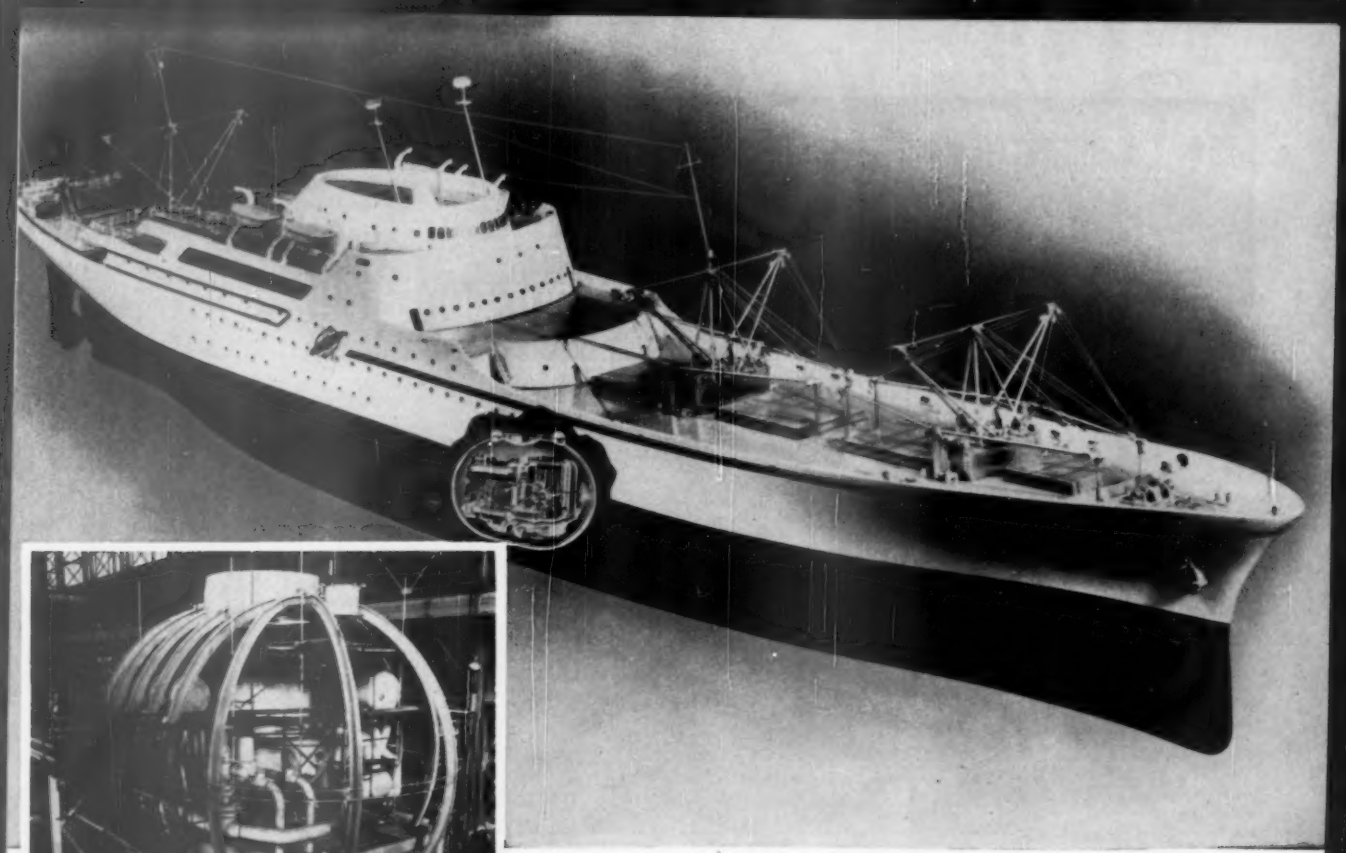
PIONEER SERVICE & ENGINEERING CO., 231 South La Salle Street, Chicago, Illinois

NEW!

Write for 40-page booklet, "Pioneering New Horizons in Power". Describes, illustrates Pioneer's engineering services, and corporate services, from financing to operation.

Sketch of "Pathfinder" commercial atomic power plant





N. S. "Savannah," the first nuclear powered passenger-cargo vessel, carries Asarco shielding lead aboard as protection against radiation. (Photos through the courtesy of the builder, New York Shipbuilding Corporation—Camden, N. J.)

TRAINING LEAD FOR ATOMIC DUTIES

ASARCO has long been a major factor in the mining, smelting and refining of lead. ASARCO's Federated Metals Division is a principal fabricator of lead in the many forms required by radiological, chemical, refining, construction, plumbing and other industries.

ASARCO's Central Research Laboratory at South Plainfield, N. J., is one of the world's centers for lead research. Here, Federated products undergo constant testing, new products are developed, and pure research learns more about the basic properties of lead. Here too, a special group of ASARCO atomic engineers help work out designs and shielding methods of major applications.

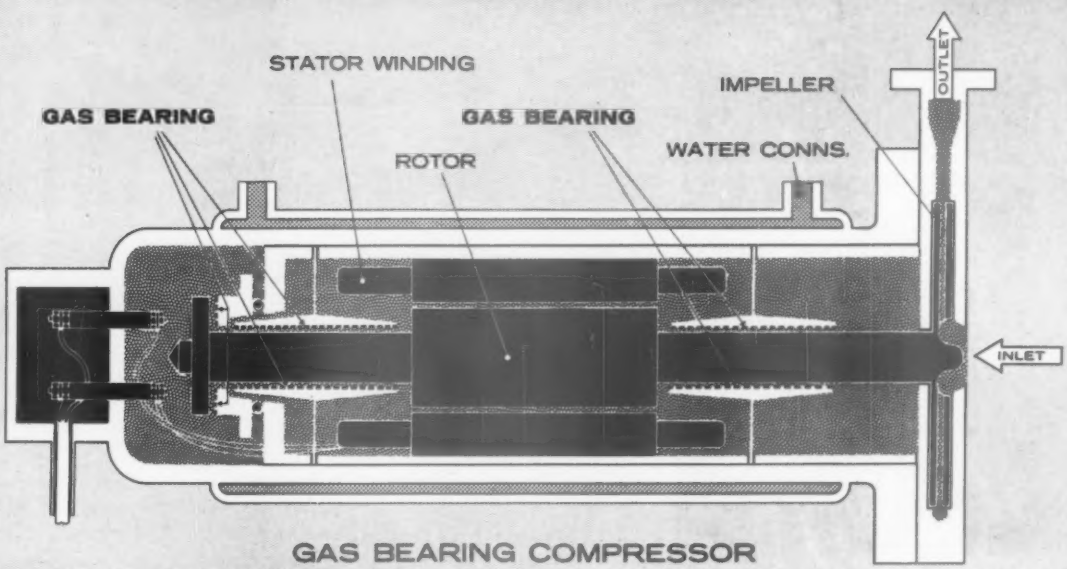
ASARCO's Lead Research Laboratory also produces High-Purity Lead (with impurities that can be measured only in parts per million) which, along with Bismuth, Copper, Cadmium, Indium and Silver of comparable purity, is supplied to the Atomic industry and to laboratories throughout the world.

Today, the millions of pounds of ASARCO lead products supplied for the atomic era are backed by the working knowledge and technical data that comes only from long and thorough experience with lead.

ASARCO

AMERICAN SMELTING AND REFINING COMPANY, 120 BROADWAY, N.Y. 5, N.Y.

Gas bearing compressors – totally enclosed, lubricant free – circulate gases up to 700°C, 2,000 psi, without contamination . . .



GAS BEARING COMPRESSOR

...ANOTHER ENGINEERING ADVANCE BY BRISTOL SIDDELEY

One of the largest manufacturers of motive power units in the world, Bristol Siddeley Engines Limited produce gas bearing compressors. The range covers a very wide performance capacity, from 0°—700° C gas operating temperature, 15—2,000 psi and 0.5—2,000 hp power input.

These Bristol Siddeley compressors have been designed specifically for systems where contamination from lubricants or leakage to atmosphere cannot be tolerated. Each unit, fitted with hydrodynamic-type gas bearings, is totally enclosed and no seals are required between the impeller and the bearings.

Gas bearings have several great advantages over oil lubricated bearings: the load-carrying capacity increases with speed, temperature and pressure; the bearings are supported on a film of the gas which is being circulated in the system, so there is no metal-to-metal contact under operating conditions and wear and maintenance are reduced to an absolute minimum; perfect cleanliness is preserved at all times.

Applications

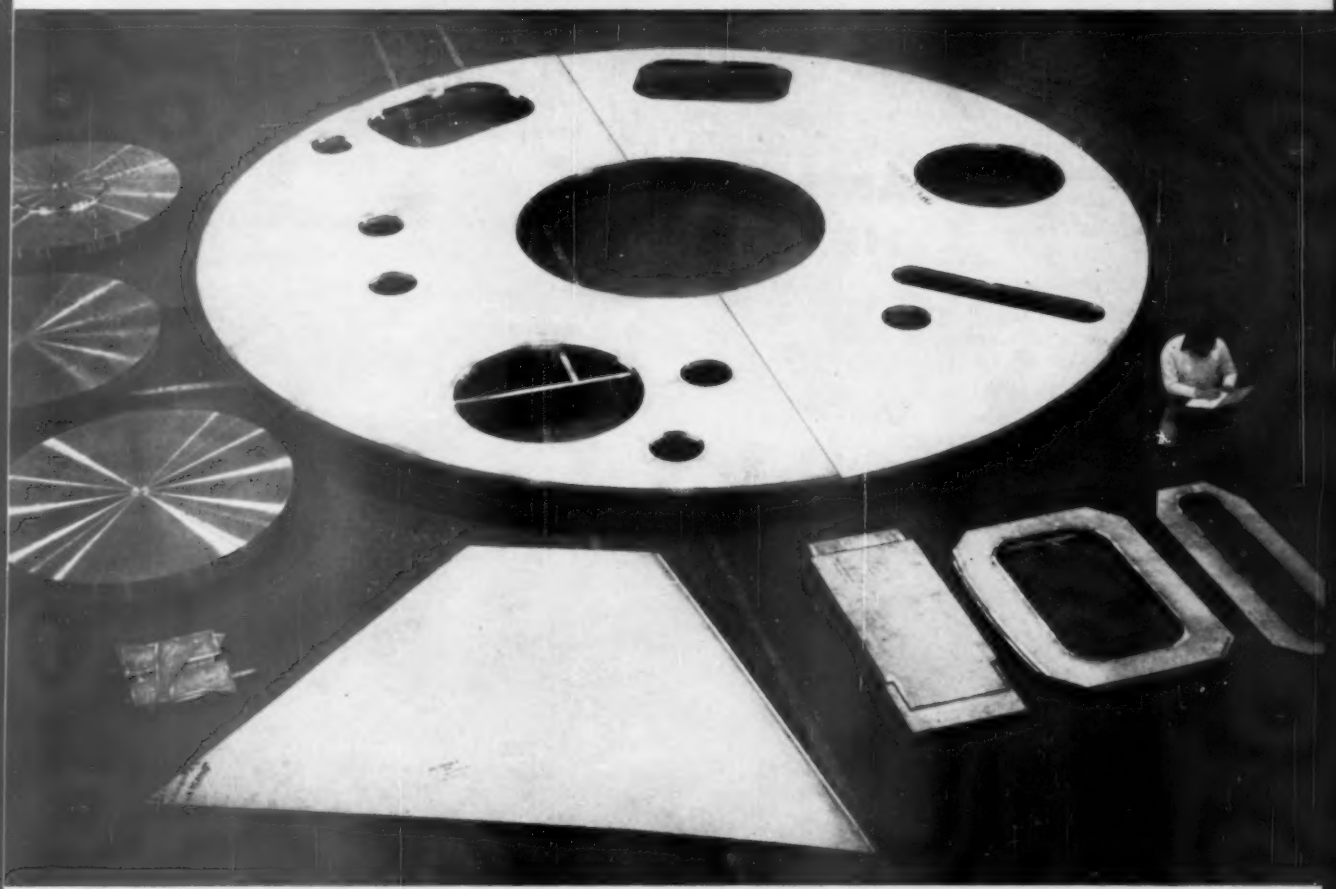
Bristol Siddeley gas bearings were developed originally to meet the extremely fine limits of operating purity and precision of manufacture demanded by the advent of nuclear engineering. But gas bearings have many other applications where a rotating shaft must be supported in such a way that no contamination and leakage can be allowed and where the supply of chemically pure fluids or gases is essential: in the textile, chemical engineering, pharmaceutical, food storage and processing industries, to name but a few.

For information about Bristol Siddeley gas-bearing compressors and gas bearings, please write Bristol Aero-Industries Limited, 200 International Aviation Building, Montreal 3, Canada.

BRISTOL SIDDELEY ENGINES LIMITED

final check

on your order for stainless steel plate from Carlson



• **Stainless steel is our only business—and we know it!** Producing to your specified tolerances in shearing, sawing, abrasive cutting, flame cutting, forming and machining stainless steel plate is a regular Carlson service. This accuracy in manufacturing saves time and money in your shop. Fabrication is easier; true-up time is cut to a minimum.

This dependable service makes Carlson a money-saving source of supply for all your stainless steel plate. You run no risk of errors which increase your costs and jeopardize your reputation and good will with your customers.

Prompt, effective service starts the moment your inquiry reaches our office. The final check of your order is done by Carlson specialists for we know your satisfaction begins right here. Take advantage of our long experience in the field. Write today, your inquiry will receive prompt attention.

C **G.O.CARLSON** *Inc.*

Stainless Steels Exclusively

MARSHALTON ROAD • THORNDALE, PENNSYLVANIA

District Sales Offices in Principal Cities

PLATES • PLATE PRODUCTS • HEADS • RINGS • CIRCLES • FLANGES • FORGINGS • BARS AND SHEETS (NO. 1 FINISH)

ELECTRICAL, MECHANICAL, CHEMICAL ENGINEERS

Investigate

Evaluating the adequacy of grid design when the grid is unevenly heated by gamma rays and subject to hydraulic loads, is basically a problem of determining thermal and mechanical stresses... Maximum stresses are calculated for a solid plate with basic modifications in the equations, such as setting Poisson's ratio to zero and solving compatibility equations between the ring and grid.

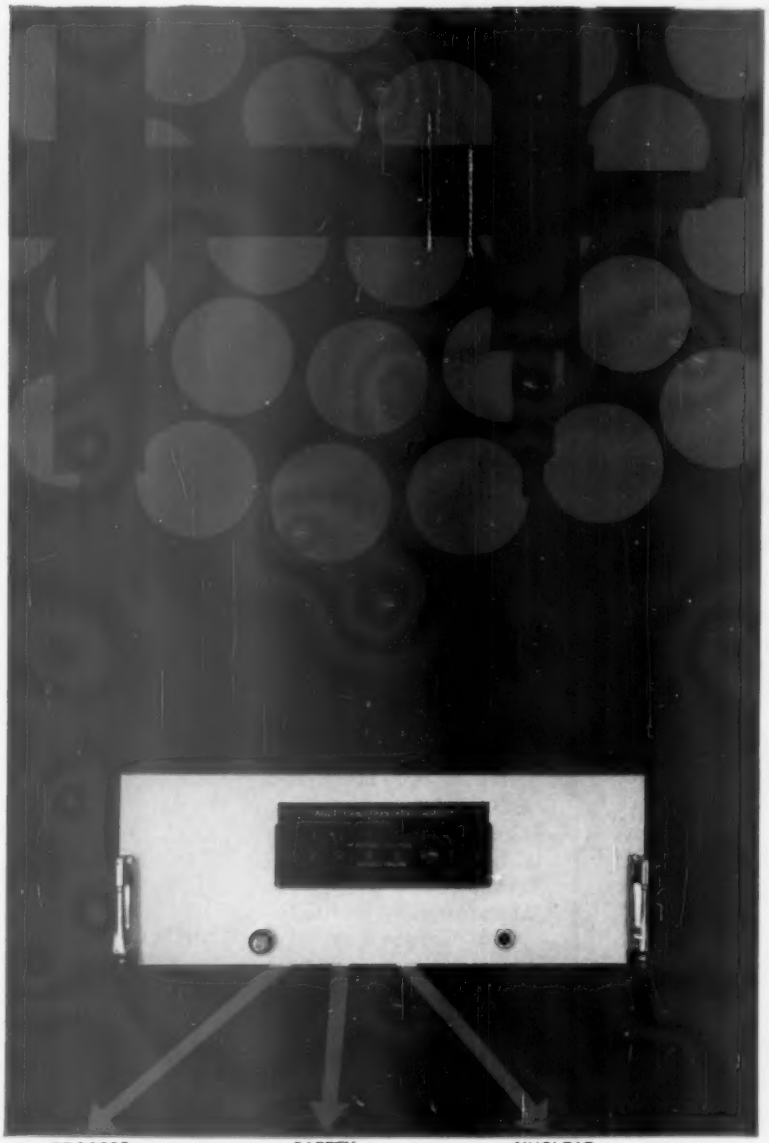
GAMMA RAY HEATING

If you are a mechanical, electrical or chemical engineer interested in a career in nuclear engineering and are a U.S. Citizen, Bettis Atomic Power Laboratory offers a dynamic program in nuclear system design and test. For additional information, write to: Mr. M. J. Downey, Dept. B-30, Bettis Atomic Power Laboratory, Westinghouse Electric Corporation, P.O. Box 1526, Pittsburgh 30, Pa.

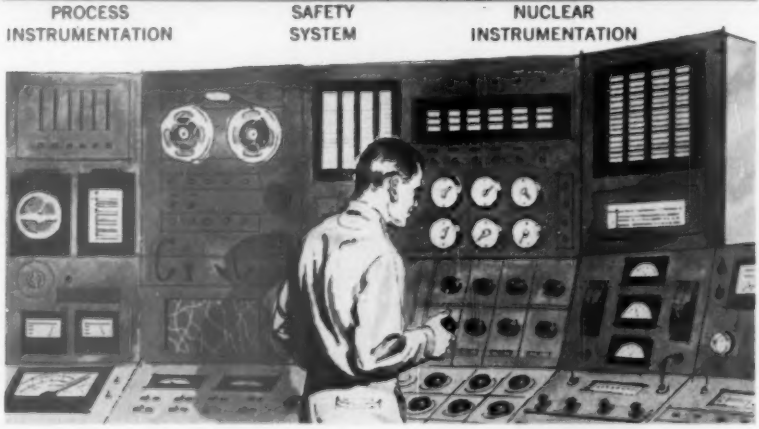
Strain Gages shown on ¼ Scale Model of PWR Top Grid

BETTIS ATOMIC POWER LABORATORY

Westinghouse



PROCESS INSTRUMENTATION | SAFETY SYSTEM | NUCLEAR INSTRUMENTATION



A TALENT FOR MODULAR NUCLEAR CONTROL SYSTEMS

Fault-isolation circuitry reduces reactor down time from hours to minutes

Hours or even days of reactor down time to search for a control system malfunction can be reduced to minutes—with self-checking and fault-isolation circuitry built into Stromberg-Carlson transistorized nuclear control systems—checks reactor process instrumentation as well as nuclear channels.

Highly skilled, specially trained technicians are not required for normal operation. Trouble is pinpointed in seconds, and plug-in, interchangeable modules can then be replaced within minutes.

Fail-safe operation achieved in Stromberg-Carlson nuclear control systems through proper use of reliable and safe solid-state circuits.

Transistorized systems available for marine power plants, portable power installations, and commercial central power stations.

Specifications upon request.

Applications engineers, engineers and scientists with reactor instrument experience interested in joining this expanding program may contact our Manager of Technical Personnel.

Visit us in the Statler Hotel, N. Y., at the A.I.E.E. Winter General Meeting.

STROMBERG-CARLSON
A DIVISION OF **GENERAL DYNAMICS**
1496 NORTH GOODMAN STREET • ROCHESTER 3, N. Y.

KANIGEN®

The proved nickel alloy chemical plating—available only from General American and its licensees

KANIGEN is a chemically and metallurgically unique process for applying a hard, corrosion and abrasion resistant surface to most metals. KANIGEN is being used successfully for coating almost everything of any size—from the inside of a tank car to a tiny surgical needle—providing extreme uniformity of coating thickness even on complex shapes. Rack, jig or barrel plating may be used with KANIGEN.

Since KANIGEN is a nickel alloy, it has many qualities which make it desirable for nuclear applications. Valves, pumps, pressure vessels, tube bundles and headers are typical of the pieces that have been successfully plated with KANIGEN.

KANIGEN is available from General American at East Chicago, Indiana; Sharon, Pennsylvania, and Compton, California, and from licensees in many cities. For further information, call or write.

KANIGEN is a trademark which identifies chemical nickel coating by General American Transportation Corporation and its licensees, the product resulting therefrom and compositions produced by them for use in chemical nickel coating.

PHYSICAL PROPERTIES

Specific gravity	7.9
Melting point	1635 °F

Electrical resistivity
approximately 60 micro-ohms/cm/cm²

Coefficient of expansion
13 x 10^{-6} cm/cm per °C or
7.22 x 10^{-6} in/in per °F

Thermal conductivity
approximately 0.0105 to
0.0135 cal/cm sec °C (calculated)

Hardness
as plated—49 Rockwell C
heat treatable to 70 Rockwell C

World's largest production facilities for chemical nickel alloy plating on
Iron
Copper
Aluminum
Titanium
Beryllium
and their alloys

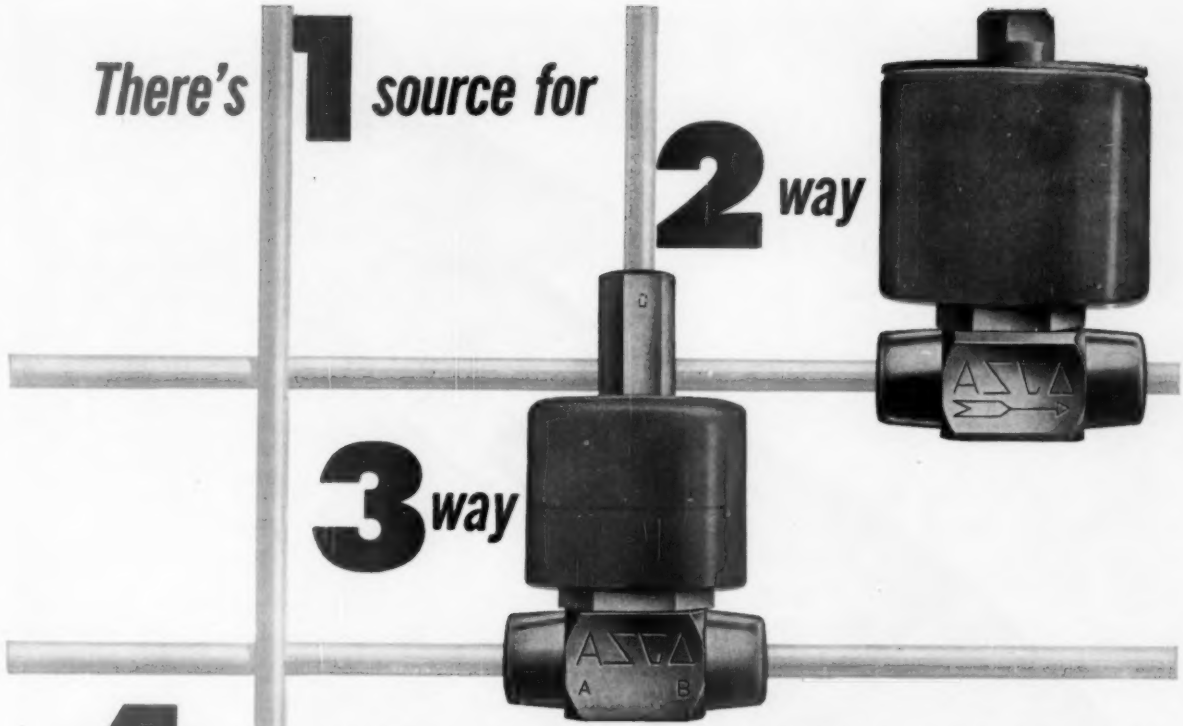
Pilot plant facilities are available for nickel alloy chemical plating on magnesium, uranium and non-metallics including thermosetting plastics, glass, ceramics.

Kanigen Division

GENERAL AMERICAN TRANSPORTATION CORPORATION

135 South LaSalle Street • Chicago 3, Illinois

There's 1 source for 2 way 3 way or 4 way MIDGET SOLENOID VALVES



SHOWN ¾ ACTUAL SIZE

World's largest stock of solenoid valves for industrial applications available for immediate delivery.

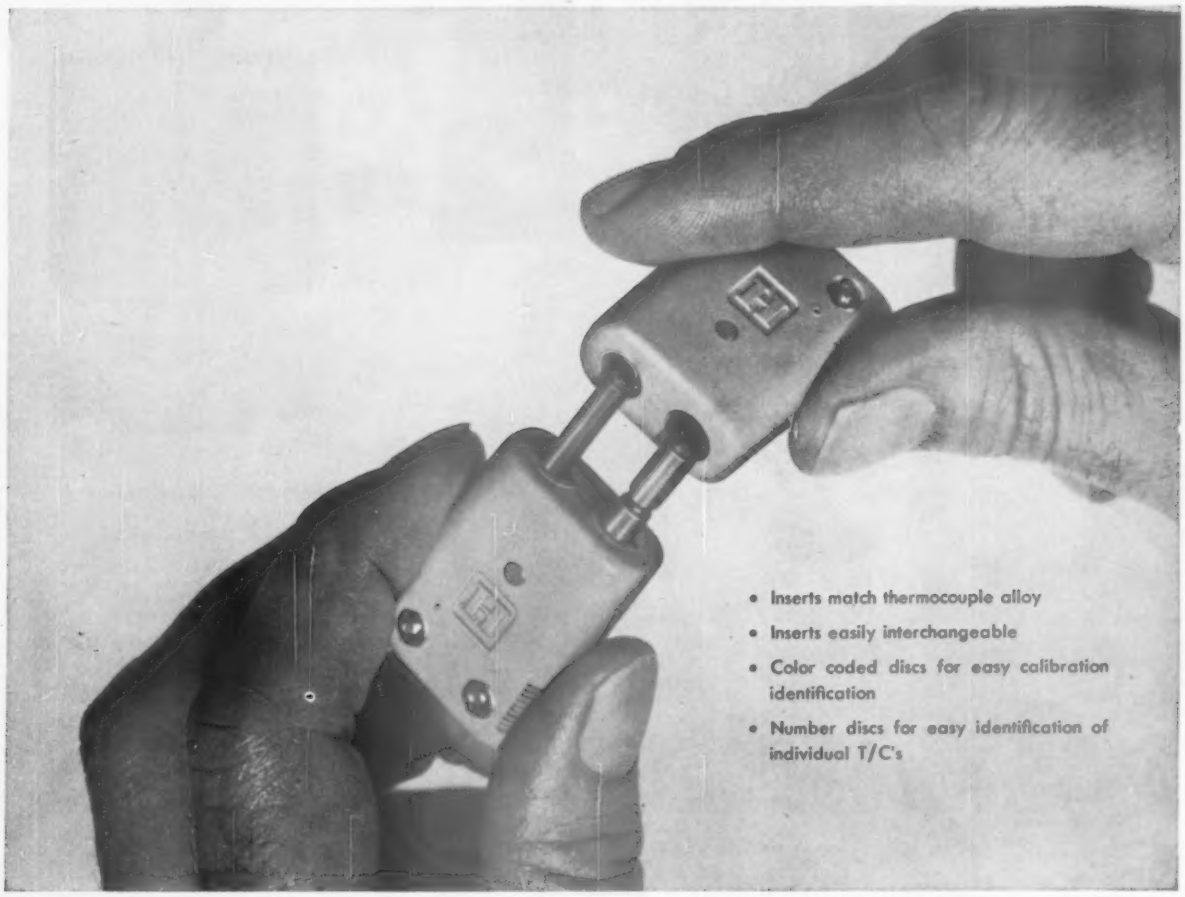
Send for Publication No. 506, Stock list and valve selection guide.

ASCO Valves

ASCO

Automatic Switch Co. 52M HANOVER RD., FLORHAM PARK, N. J., FRONTIER 7-4600

AUTOMATIC TRANSFER SWITCHES • SOLENOID VALVES • ELECTROMAGNETIC CONTROL


• Inserts match thermocouple alloy
• Inserts easily interchangeable
• Color coded discs for easy calibration identification
• Number discs for easy identification of individual T/C's

NEW *QuiK-Konnect** thermocouple components

For accurate, swift, and foolproof connection of thermocouples to extension wire

New *QuiK-Konnect* plug and jack bodies give fast, easy, and foolproof extension wire connections in plant, laboratory or test cell installations.

Inserts have different diameter positive and negative poles, for foolproof connection . . . are extremely easy to remove for field calibration change or replacement. Various tube adapters are available to protect small-diameter thermocouples, and cable clamps can be supplied to protect extension wires from fraying or tearing.

The *QuiK-Konnect* line, in addition to plugs and jacks, includes:

1. Single-jack panel that fits ¾-in. knockout.
2. 4-point jack panel that fits standard electrical outlet box.
3. Multiple jack strips.
4. Custom-built multiple jack panels.
5. *QuiK-Kords** for patch programming multiple jack panels.

You can get complete details from your nearby Honeywell field engineer. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, 21 Penn St., Fall River, Mass.

*Trademarks

75th YEAR — PIONEERING THE FUTURE

Honeywell

H HONEYWELL — First in Control — SINCE 1885

One of a series

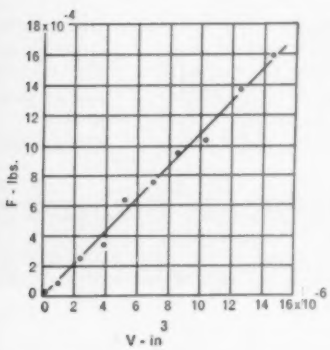
On the riddle of rolling friction

It doesn't take much to roll a hard ball across a hard, smooth, level surface – actually only about 0.00001 times the normal force acting vertically on the ball. But by careful measurement of this tiny rolling force, scientists at the General Motors Research Laboratories are helping to unravel the riddle of rolling friction.

An important relationship recently uncovered in this fundamental study: the rolling force is proportional to the volume of material that is stressed above a certain level. As a result, a GM Research group have not only confirmed the hypothesis of *how* a rolling ball loses energy (Answer: elastic hysteresis) but also have learned *where* this lost energy is dissipated (Answer: in the interior of the material, not on the surface). Mathematical analyses have indicated the exact shape of the elastically stressed volume in which all the significant frictional loss takes place.

The purpose of friction research at the GM Research Laboratories is to learn more about the elastic and inelastic behavior of materials. This knowledge – of academic interest now – will eventually give GM engineers greater control of energy lost through friction. This is but one more example of how General Motors lives up to its promise of "More and better things for more people."

General Motors Research Laboratories
Warren, Michigan



Relationship of rolling force to elastically stressed volume.

SPS RELIABILITY / *A dynamic standard of predictable performance*

SPS Nuclear Division receiving inspector uses ultrasonic probe—comparable in a sense to radar—to verify absence of internal flaws in precision forging destined to become part of reactor vessel closure head in nuclear-powered submarine.

Pre-induction physical for a reactor component

Steel received by the SPS Nuclear Components Division is already a pretty sophisticated material. It comes from one of the few mills qualified to meet certain rigid Government specs. It is accompanied by a detailed affidavit of analytical tests—physical, chemical, ultrasonic, macro, intergranular, stepdown—conducted under the surveillance of both military and SPS field inspectors.

Nevertheless, the as-received material is considered by SPS to be merely a candidate for machining. New specimen slugs are cut; all tests are performed again—under the strict control of SPS laboratories, a facility unequaled in the industry. Following laboratory approval, a requirement never deviated from, the forging is serialized, assigned an individual record folder, and released to production.

And this is just the beginning. Every dimension of every part is recorded during manufacture (only SPS takes the trouble to compile this in-process data). Then when the part is finished, all records are put aside, and every dimension is rechecked—an operation that may take up to 6 hours and involve hundreds of measurements, many to ±.0005 inch.

Why these extraordinary precautions? Simply because these parts must function with absolute reliability, oftentimes in inaccessible locations. If you have requirements for such components (for reactors or for conventional power-producing machinery), contact SPS—manufacturer of precision threaded fasteners and allied products in many metals, including titanium. Request new Folder 2499.

NUCLEAR COMPONENTS Division **SPS**

JENKINTOWN 45, PENNSYLVANIA

TO OUR BUSINESS FRIENDS

This is the age of breakthrough—the era of new frontiers.

And it is a time of challenge to American industry to meet the demands which call for fresh, new thinking.

Wolverine Tube is proud of the fact that it is pacing the industry. The research and development program, for example, has the tubing industry's most complete facilities devoted exclusively to probing into and improving the technology of tube manufacture.

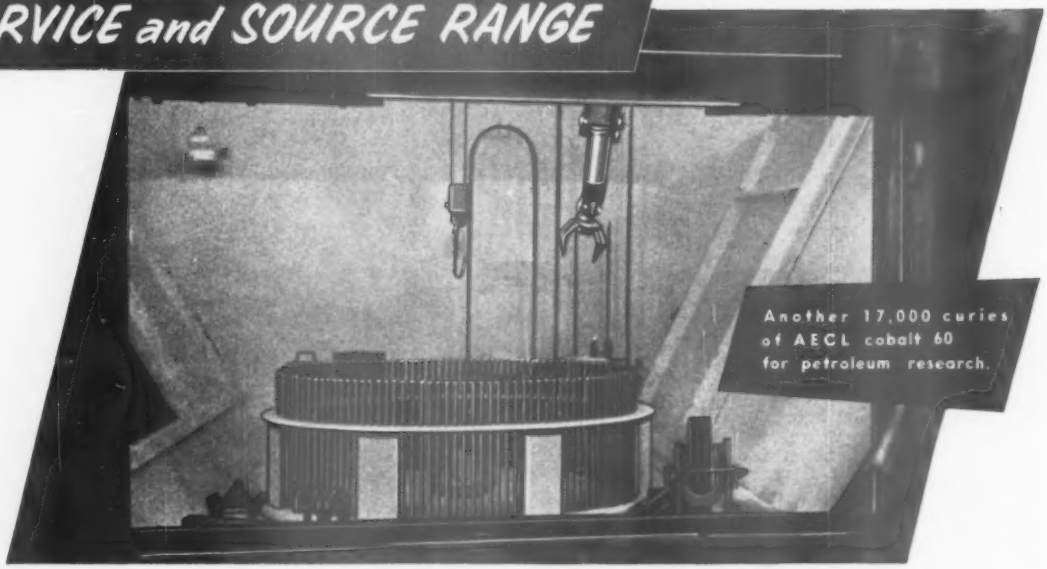
From this continuing program have come improvements to existing products and the development of entirely new ones. And with these facilities, Wolverine's skilled technicians are extruding tube and shapes from such metals as zirconium, columbium, titanium, tantalum, molybdenum and others.

If you must meet the special requirements of today —and tomorrow—give us an opportunity to help. Just write.

WOLVERINE TUBE
DIVISION OF
CALUMET & HECLA, INC.
17200 Southfield Road
Allen Park, Michigan
Manufacturers of Quality Controlled Tubing and Extruded Aluminum Shapes

COBALT 60

SERVICE and SOURCE RANGE



A "Weldcaps" Cobalt 60 source supplied by AECL, in the hot cell at SINCLAIR RESEARCH LABORATORIES INC., Harvey, Illinois.

For your Gamma Irradiation requirements choose A.E.C.L. COBALT 60

- **Can be supplied in kilocurie quantities.**
- **Versatile PELLET and SLUG forms enable you to choose any source configuration you desire.**
- **AECL's highly acclaimed "Weldcaps" (stainless steel, welded capsules) are available in a wide range of standard sizes. Special sizes can be made up as required.**

Cobalt 60 is

- Penetrating — (excellent uniformity of dose),
- Reliable — (no complicated electrical equipment to break down at critical times),
- Constant — (calibrate once, then forget about it),
- Simple — (no induced activity in irradiated materials; Monochromatic radiation).

IRRADIATOR DESIGN and FABRICATION SERVICE

Take advantage of AECL's years of experience and knowhow for assistance regarding any aspect of your research or production irradiator requirements.

For further information, please write to —

ATOMIC ENERGY OF CANADA LIMITED

Commercial Products Division • P.O. Box 93 • Ottawa • Canada

59 2 KC

Tubexperience in action

Autoclave corrosion test of Inconel heat exchanger tubing.

Now! Nuclear quality Inconel* heat exchanger tubing for highest stress corrosion resistance

Inconel, nickel-chromium alloy, has been added to Superior's line of Nuclear Quality Heat Exchanger Tubing. This analysis offers unusually high stress corrosion resistance. It is highly resistant to intergranular and selective attack in spite of applied or residual stress and exposure to liquid and vapor phase water, even if the primary or secondary water contains oxygen and chloride ions. Typical of its resistance to corrosion is the following: at 650°F, 25 ft/sec flow, the corrosion rate is less than 12 mg/(dm^2)/month. In Superior's Inconel tubing, cobalt and carbon content are held to restrictive levels. Control of cobalt content reduces radiation hazards.

For particulars on Nuclear Quality Inconel Alloy Heat Exchanger Tubing, write for STC-107, Superior Tube Company, 2027 Germantown Ave., Norristown, Pa.

*Trademark of the International Nickel Co.

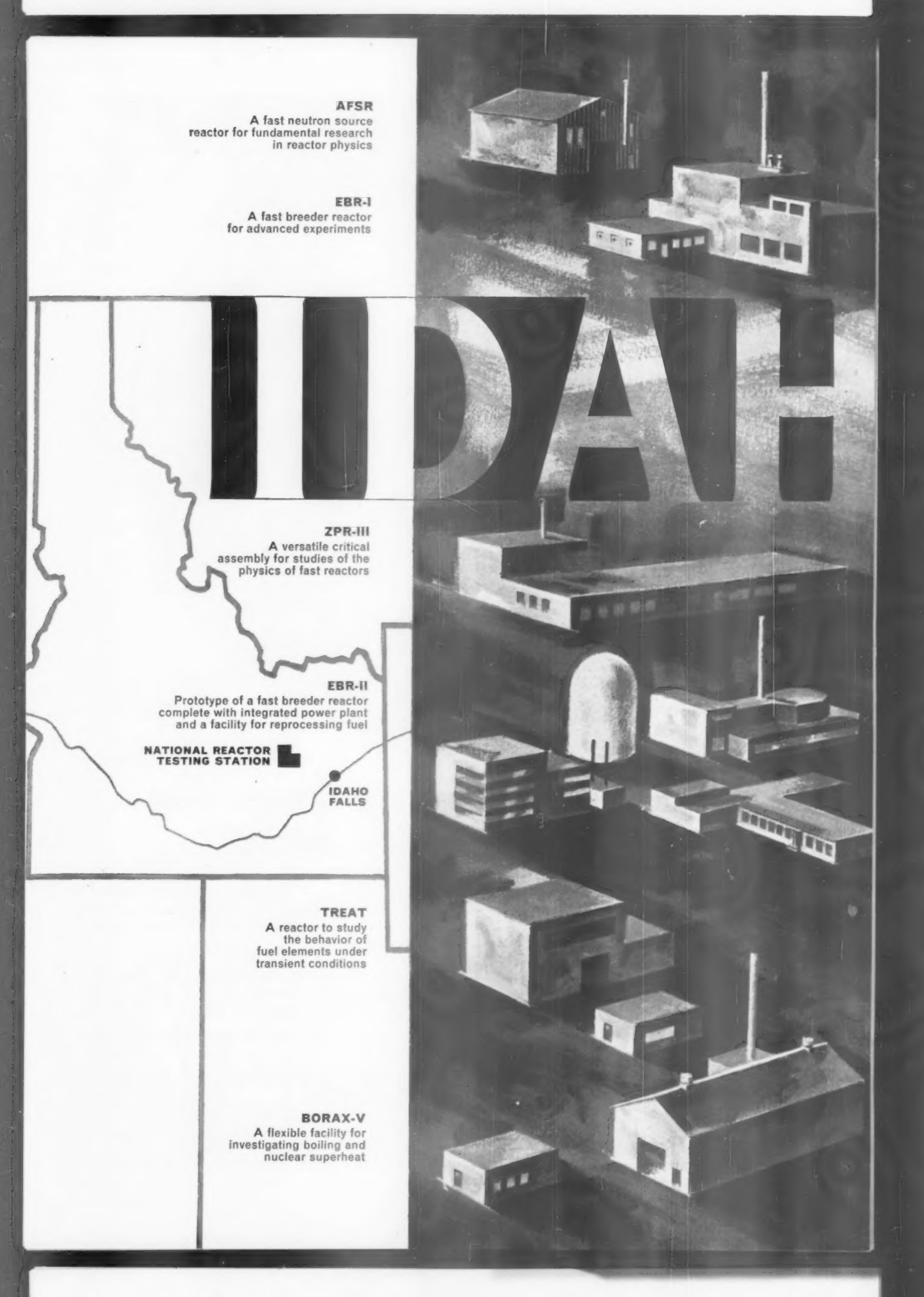
Superior Tube

The big name in small tubing

NORRISTOWN, PA.

All analyses .010 in. to ⅝ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST


AFSR
A fast neutron source reactor for fundamental research in reactor physics
EBR-I
A fast breeder reactor for advanced experiments
IDAHO
ZPR-III
A versatile critical assembly for studies of the physics of fast reactors
EBR-II
Prototype of a fast breeder reactor complete with integrated power plant and a facility for reprocessing fuel
NATIONAL REACTOR TESTING STATION
IDAHO FALLS
TREAT
A reactor to study the behavior of fuel elements under transient conditions
BORAX-V
A flexible facility for investigating boiling and nuclear superheat

The Idaho Division of Argonne National Laboratory has a distinguished record of contribution toward realization of our nation's objective of economic nuclear power. Included in the proud chronicle of its historical accomplishments toward peaceful applications of the atom are:

The first generation of useful amounts of electricity from the atom, (EBR-I, 1951);

The first demonstration of breeding of nuclear fuel, proving the feasibility of producing in a reactor more fuel than is consumed during operation, (EBR-I, 1953);

The first boiling reactor, verifying the practicability of using nuclear-created steam directly in a turbogenerator system to produce electricity, (BORAX-I, 1953);

The first use of atomic power to light a town (Arco, Idaho, by BORAX-III, June, 1955).

Concepts today that are programming America's future

Ambitious plans are still in the making at Argonne's Idaho Division. This unique proving ground, operated in close cooperation with the other divisions of Argonne National Laboratory, provides an unsurpassed variety of reactors and associated research programs to challenge the creative scientist and engineer.

With four reactors in operation and two more under construction, many opportunities have been created for physicists, mathematicians, chemists, chemical engineers, electrical engineers, mechanical engineers, metallurgical engineers, and nuclear engineers.

Interesting, specialized problems exist for the pure theoretician. There is also opportunity for those who wish to participate in applied projects from conception through design, construction, and test phases.

Organization and administration aim both for individual productivity and interdisciplinary cooperation. Basic and applied research are promoted at the professional level as full-time assignments.

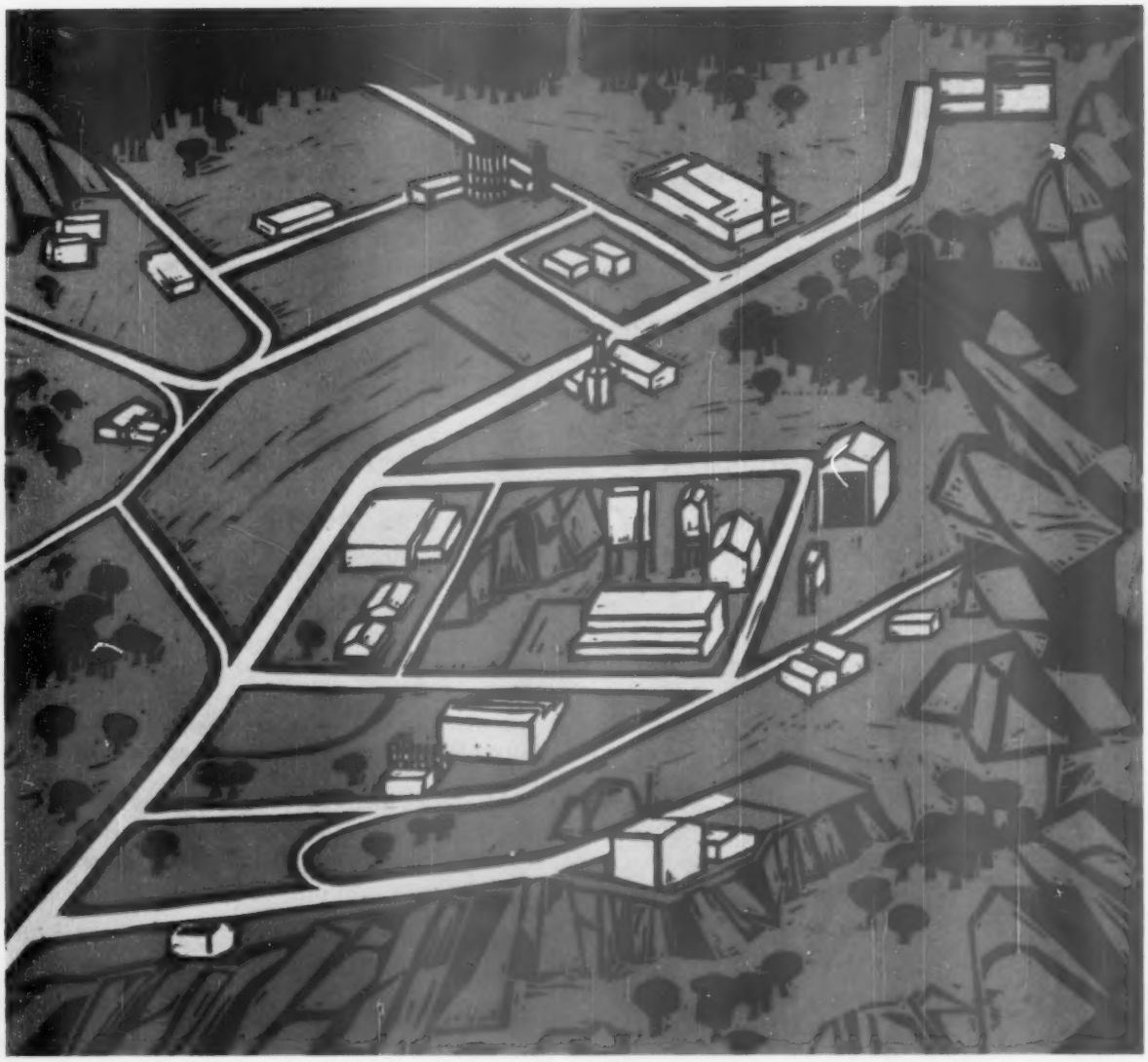
Argonne families enjoy the dry, sunny and healthful climate of the Idaho Falls area, where Western-style family living is at its best. Outdoor attractions such as Yellowstone Park, the Grand Tetons, and Sun Valley, are close at hand for enjoyment by the whole family.

PLEASE WRITE TO:
Meyer Novick, Director
Idaho Division
Argonne National Laboratory
P. O. Box 2528-IA3
Idaho Falls, Idaho

IDAHO DIVISION
Argonne
NATIONAL LABORATORY
Operated by the University of Chicago under a contract with the United States Atomic Energy Commission

Many openings exist for similarly qualified scientists and engineers at the Lemont site in suburban Chicago. Particular interest in opportunities there should be directed to:

Louis A. Turner, Deputy Director
P. O. Box 299-IA3
Lemont, Illinois



AI's extensive field laboratory is located in California's Santa Susana Mountains. *Woodcut by Edward Kysar.*

How can A.I. facilities help you plan a Nuclear Program?

In the picturesque Santa Susana mountains near Los Angeles, Atomics International has built an extensive field laboratory for research, engineering and testing in the nuclear sciences. Here, and at a headquarters complex in the valley below, men who pioneered the creative uses of atomic energy are applying their experience to develop advanced nuclear reactors and associated equipment.

Fourteen years of experience in developing various types of reactors for the Atomic Energy Commission and other organizations have given the men of Atomics International a collective background unparalleled in the industry. The facilities at their disposal are among the most sophisticated and extensive in the world.

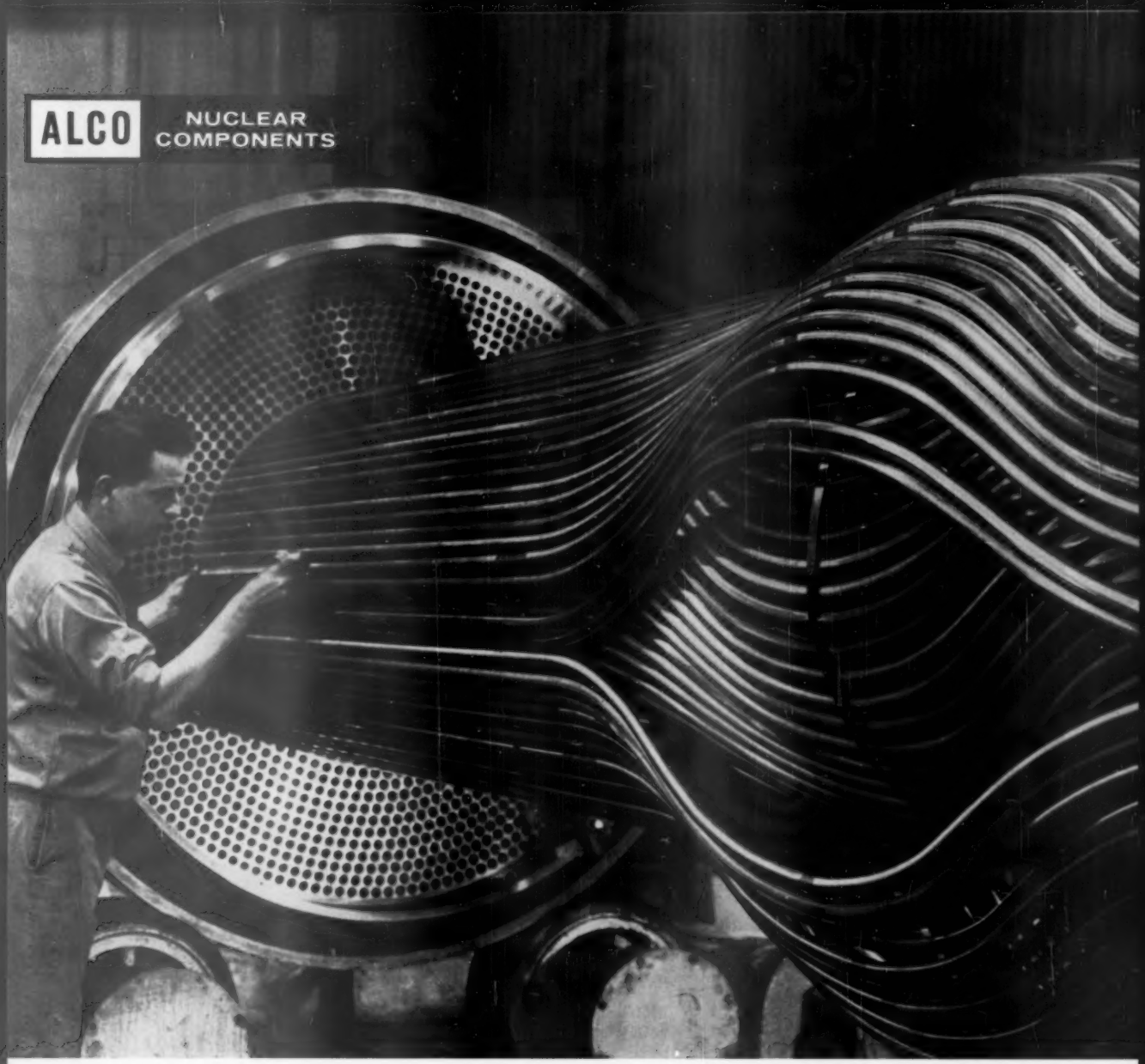
Results of AI's work have been demonstrated in projects for the AEC which include the Organic Moderated Reactor Experiment at the National Reactor Testing Station in Idaho and the Sodium Reactor Experiment at the company's field laboratory. Additionally, AI built and is operating SNAP II, a 220 pound prototype reactor to produce three kilowatts of electricity for space vehicles.

Atomics International is also building large power reactors for electric utilities in Ohio and Nebraska under AEC programs. Studies are underway for other power reactors in the United States and Europe. Research reactors have been built by AI for Denmark, Germany, Italy, Japan, Puerto Rico and several sites in the United States.

For details contact: ATOMICS INTERNATIONAL, Canoga Park, California, U.S.A. Cable address: ATOMICS.

ATOMICS INTERNATIONAL
A DIVISION OF NORTH AMERICAN AVIATION, INC.
PIONEERS IN THE CREATIVE USE OF THE ATOM

Other offices in: Washington, D.C., U.S.A.; Geneva, Switzerland. Affiliated with: INTERATOM, Bensberg/Cologne, Federal Republic of Germany and DYNATOM, Paris, France.



ALCO's *unique sine-wave heat exchangers are being installed at Power Reactor Development Co.'s Enrico Fermi Atomic Power Plant.*

THE NEW SHAPE OF THERMAL EXPANSION

The new concept of sine-wave tubes to absorb thermal expansion—first developed by ALCO Products, Inc. for the submarine *Nautilus*—is now being applied in three heat exchangers for the Enrico Fermi plant. The big ALCO units exchange heat between the two sodium loops in the plant, with each exchanger having a capacity of 500 million Btu per hr.

In operation, the sine-wave tube bundles absorb thermal shock loads by flexing at the bend of each tube. Thus, expansion joints are eliminated, greatly increasing the reliability and integrity of the equipment.

Engineering ingenuity, exemplified by the sine-wave tube, is one of the reasons why ALCO nuclear components are incorporated in the majority of nuclear plants—Naval, civilian and military. Ninety per cent of such plants in the U.S. employ ALCO components: reactor vessels, steam generators, pressurizers, heat exchangers, core structures, control-rod drives.

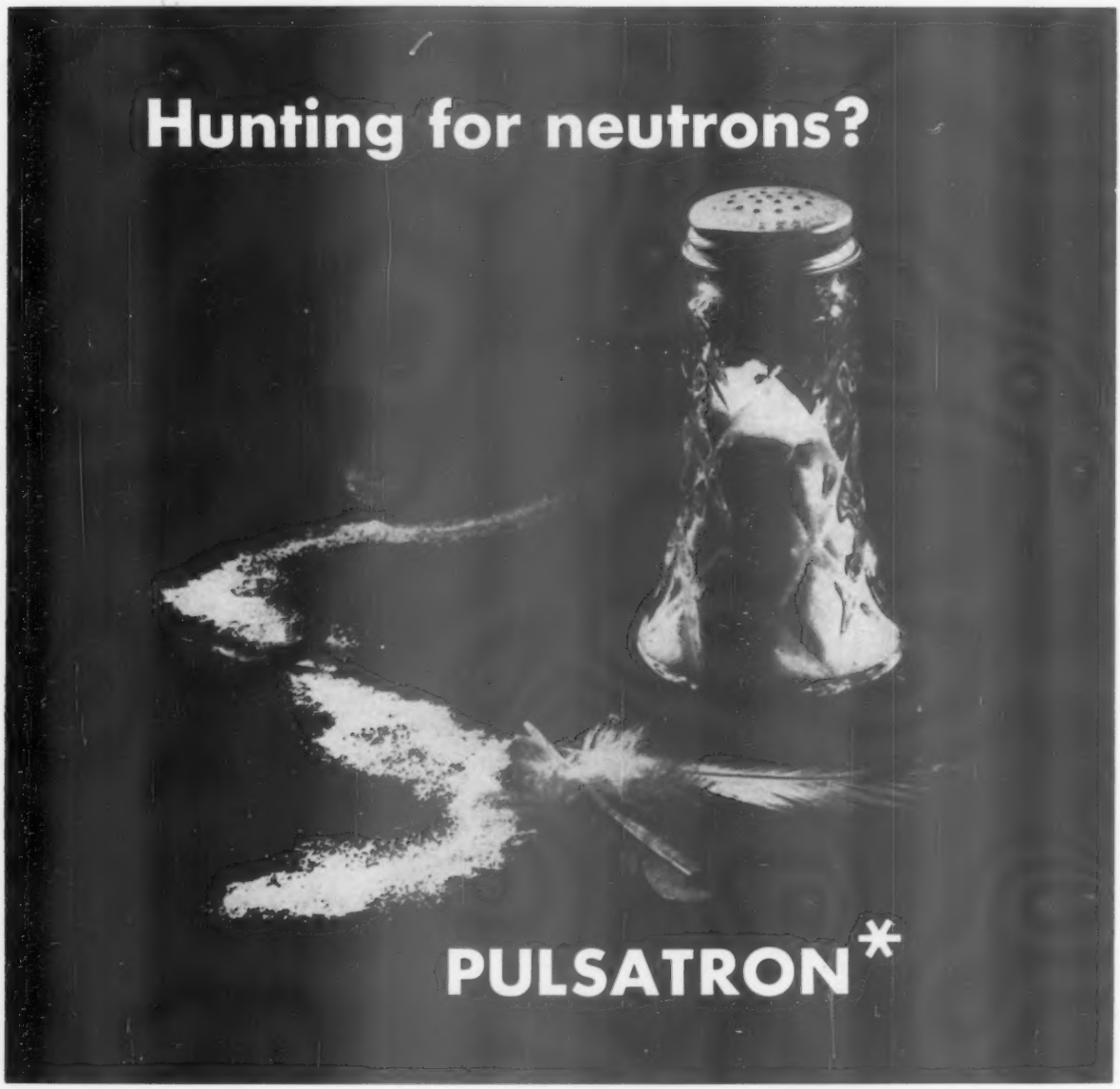
ALCO is also an experienced designer and builder of complete nuclear power systems.

If you seek engineering and manufacturing excellence for your nuclear equipment, let ALCO prove its capability. Call your nearest ALCO sales office, or write ALCO Products, Inc., Dept. 139, Schenectady, N. Y.

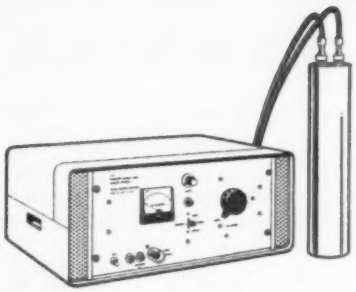
ALCO PRODUCTS, INC., New York · Sales Offices in Principal Cities · Makers of: *Nuclear Reactors and Components · Locomotives · Diesel Engines · Heat Exchangers · Springs · Steel Pipe · Forgings · Oil Field Equipment · Weldments*

ALCO

Hunting for neutrons?



PULSATRON*



* the Kaman neutron source
small - lightweight - portable

10^7 neutron/pulse - nominal.
5 microseconds — pulse length.
Adjustable - 1-10 pulses/sec.
H^3 (d, n) He^4 reaction.
Accelerator Unit — 4" OD x 18" long.
Control Unit — 21¾" x 15¼" x 10½".

The NT-60-8 Pulsed Neutron Generator Assembly . . . *an Exclusive Development by*

KAMAN NUCLEAR
COLORADO SPRINGS, COLORADO
A Division of the Kaman Aircraft Corporation

Research and Development in Nuclear Weaponry and Instrumentation.

Scientists and Engineers . . . Live and Work in the fabulous Garden of the Gods vacationland. Write Employment Division 13

To be in the know—you've got to

1960 NUCLEAR CONGRESS
APRIL 4-7...COLISEUM
NEW YORK CITY

Technical programs directed to engineering level, including forty-seven sessions on all phases of the peaceful use of atomic energy... plus an atomic exposition that will feature the products and services of one hundred and thirty-five major companies in the nuclear industry.

PLAN NOW TO ATTEND!

Registration at the Coliseum starts April 4. Meanwhile, get the facts. For your advance copy of the full program, mail this convenient coupon ▶

1960 NUCLEAR CONGRESS
ENGINEERS JOINT COUNCIL, INC.
29 West 39th Street • New York 18, New York

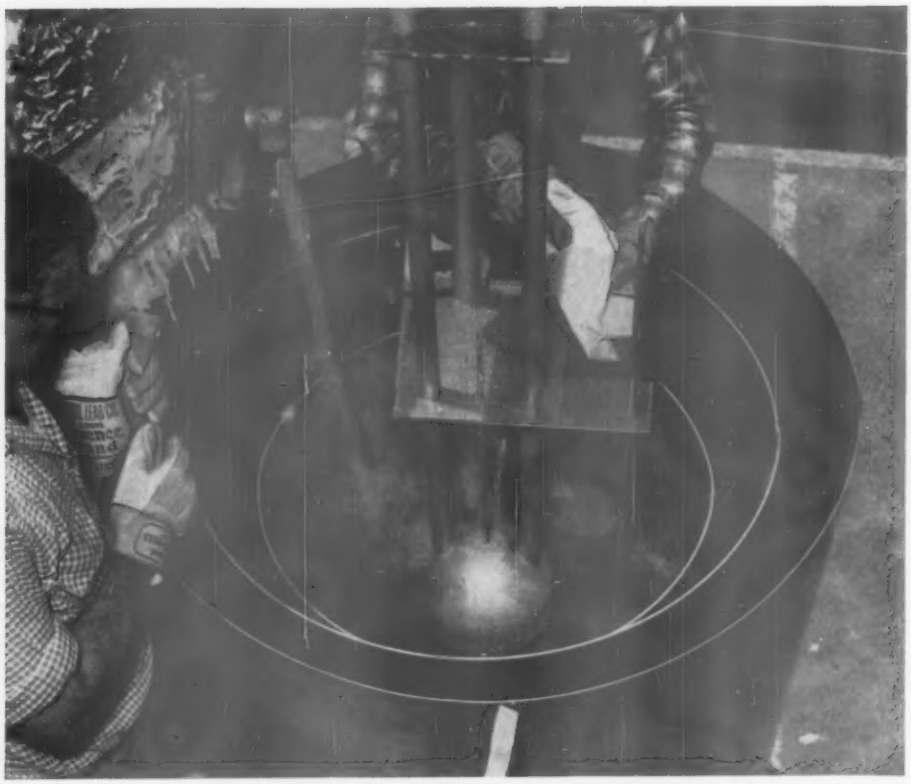
Please send me an advance copy of the program for the 1960 Nuclear Congress, to be held April 4-7 in New York Coliseum.

Name .....

Company .....

Address .....

A2



Where cast-to-fit shielding is impractical poured-in lead shot fills the bill

. . . helps Atomics International provide lab reactors for training and research.

For handling ease, for economy, no gamma shielding material can compare with National Lead Company's free-flow lead shot.

Here's a case in point . . . Atomics International's new 10-watt, L-77 Aqueous Homogeneous Research Reactor. As the picture above demonstrates, the shot is simply poured into the space allotted for shielding. Because each pellet is round and smooth, National Lead shot freely flows into and packs every nook and cranny . . . molds itself to any wall contour. No vibration is needed. No settling takes place after space is filled.

National Lead shot, in suitable sizes — .020" to .095" — has about 70% of the efficiency of solid extruded lead and lends itself well to dual or triple-purpose shielding since both moderator materials and neutron absorbers can be uniformly intermixed with it.

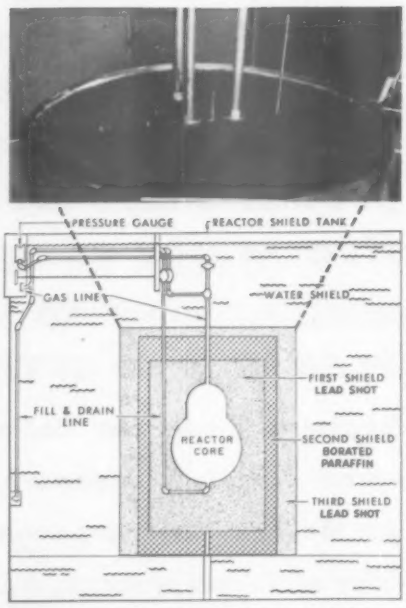
May be drained off and replaced almost as easily as water

For easy access to equipment elements located within or passing through shielding spaces, outlets and inlets can be arranged that permit lead shot to be run out and run in almost as easily as a liquid.

When it comes to lead shielding, look *first* to National Lead. National Lead supplies lead in every shielding form, shot, brick, wool, sheet, plate. *In addition, National Lead fabricates gamma ray certified lead shieldments to any thickness.*

National Lead also supplies an invaluable intangible — the extensive knowledge and experience in shielding problems gained by its own activities as a producer of nuclear fuel elements and reactor components, as operator of the AEC Feed Materials Production Center at Fernald, Ohio and as participant in Industrial Reactor Laboratories, Inc., Plainsboro, N. J.

If you have a gamma shielding problem, we'll be glad to help.



How contained shot shields Al's L-77 Laboratory reactor. Drawing shows arrangement of shells. Large picture shows shot being poured into inner shell. Small picture shows shot-filled shield.

National Lead Company

General Offices: 111 Broadway, New York 6, N. Y. • *Offices in principal cities*

Dutch Boy PRODUCTS

NUCLEONICS

JEROME D. LUNTZ, *Editor and Publisher*

FEBRUARY, 1960

The Need for a Proper AEC Attitude

Considerable criticism is presently being leveled at the Atomic Energy Commission for engaging in activities in competition with private industry. Some of this criticism has been invited by the AEC acting on a Bureau of the Budget request for an analysis of all potentially competitive work in government. Some of the criticism has been spontaneous.

Regardless of the merits of the criticisms—which we expect to examine in a later editorial—rather basic questions have been raised on what we in the U. S. want from our atomic energy effort and how we want to reach our goals.

Looking back at the history of the program, we see that, when the AEC took over in 1947, its big immediate task was to build a weapons stockpile. About six years later, when this first task was well in hand, AEC, in partnership with the State Department, began a major push to use atomic energy as an instrument of foreign policy, via the "atoms-for-peace" program. In the past six years, although the atoms-for-peace effort has fallen short of the mark set for it, the U. S. has been able to foster nuclear developments in many countries.

Thus, it is clear that AEC has been quite mindful of two of the mandates given it in Sec. 1 of the Atomic Energy Act—to make "the maximum contribution to the common defense and security . . . and to promote world peace."

As important as these areas are—and they are of transcendental importance—there is also an implicit mandate in the law for AEC to see that the multibillion dollar public investment in atomic energy bears fruit for the American people and American industry.

Unfortunately, we are long overdue on reaping the fruits of this investment. With the world's first nuclear reactor having been born 17 years ago and with the first power-producing reactor having been born 15 years ago, we in the U. S., by the year 1960, should have achieved economically competitive atomic power in the U. S., we should have achieved widespread radiation use in industry, and, as a consequence, we should now have a thriving nucleonics industry.

Although we are on the threshold of achieving all three, we have not yet arrived. There are many reasons for this, including AEC's not paying enough heed to civilian technology in the early years and there being insufficient incentive for industry to spend more of its own money in more recent years.

But rather than look at the past, it would be more constructive to look into the future. The nucleonics industry can probably achieve its goals under its own steam. But it would be healthier for the U. S.—and the time is long overdue—for AEC to go all out on fostering a vigorous nucleonics industry. The details of what might be done are perhaps not as important as the attitude. For if the right attitude is there, AEC would probably then take some of the studies it has been doing recently and incorporate them as part of a larger plan that would point to bringing about as quickly as possible: (1) competitive atomic power in the U. S., (2) widespread radiation use, and (3) a healthy nucleonics industry. And, again, if the right attitude is present, AEC facilities and industry would each be assigned their proper roles to form the strongest partnership for reaching these three goals.

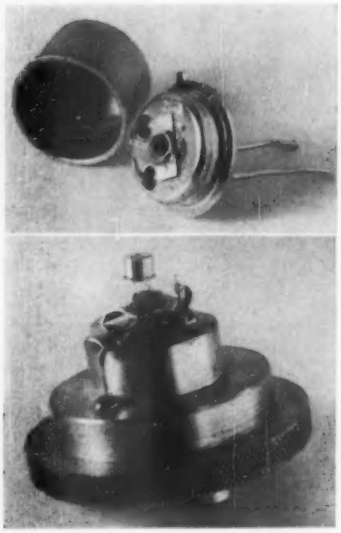


FIG. 1. SMALL SIZE OF DIFFUSED-JUNCTION SILICON DETECTOR is revealed in photographs. Small cap in both pictures has diameter of only 5/16 in.

Tiny Semiconductor

By STEPHEN S. FRIEDLAND and JAMES W. MAYER

Nuclear Electronics Laboratory, Hughes Aircraft Company, Culver City, California

and JOHN S. WIGGINS

Semiconductor Division, Hughes Aircraft Company, Newport Beach, California

A shallow diffused *p-n* junction operated with reverse bias forms a space-charge region that functions as a fast, solid-state ionization chamber

SEMICONDUCTOR DEVICES have many advantages as radiation detectors. They are small, rugged and fast. Like ionization chambers they produce current pulses proportional to the energy deposited in their sensitive volumes. Thus they can be designed to give a high-resolution response proportional to incident particle energy. They are simple, requiring no high-voltage supplies, cooling, windows or flow of gases.

Semiconductor junction detectors are not new. Since 1951 when McKay (*1*) detected α-particles incident on a *p-n* junction, Mayer (*2*), Dabbs and coworkers (*3*), and McKenzie and Bromley (*4*) have added to the subject.

By a shallow diffusion (less than 1 micron) of phosphorous into *p*-type high-resistivity silicon, we have made devices that act as particle detectors and energy spectrometers for heavy charged particles—protons, alpha particles, fission fragments—and preliminary results show that beta detection has also been achieved. With suitable reverse bias the devices produce a linear response to protons up to 4.5 Mev and to alpha particles up to at least 20 Mev. Pulse-height distributions have been measured with an energy resolution of 0.6% at 6 Mev (half width at half maximum divided by pulse height). Response time is less than that of the circuits with which they are measured ($<3.5 \times 10^{-9}$ sec).

Figure 1 shows the device mounted and ready for use. The detector itself is 0.5 mm thick and has a sensitive area of about 2 mm diameter. Larger area detectors are currently being fabricated and their properties investigated.

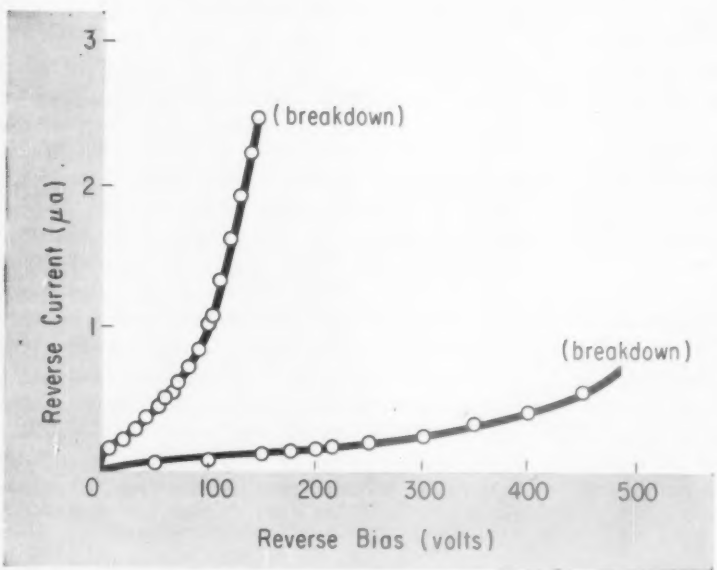


FIG. 3. CURRENT-VOLTAGE characteristics of two kinds of detectors made by diffusing phosphorus into p-type silicon

OPERATING PRINCIPLES

Figure 2 shows the sensitive portion of a solid-state detector. A shallow diffusion of phosphorous forms a *p-n* junction near one surface of a slab of high-resistivity *p*-type silicon. Reverse bias establishes a depletion or space-charge region on both sides of the junction.

Detection and spectrometry consist in the creation of hole-electron pairs by an entering charged particle and collection of the charge as a current pulse across the junction. This current produces a measurable voltage pulse, the height of which is a direct indication of

Is Fast, Linear Detector

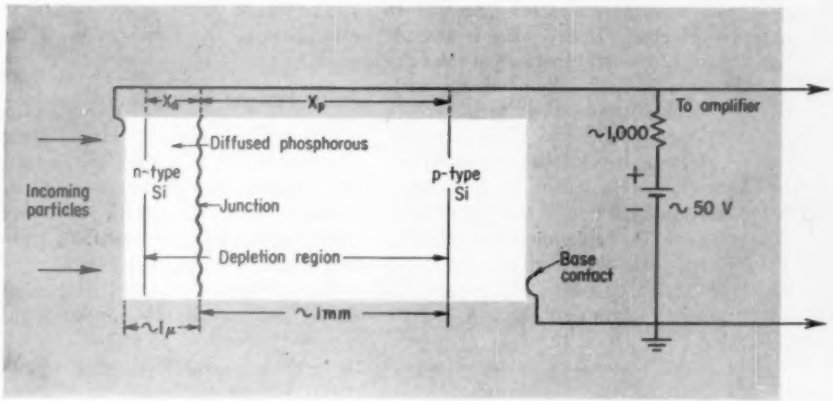


FIG. 2. DETECTOR GEOMETRY shows p-n junction about 1 micron from surface and sensitive volume (depletion region) about 1 mm thick

the particle energy. Thickness of the depletion region on each side of the junction is given approximately by $X = (\epsilon V/2\pi qN)^{1/2}$ where ϵ = dielectric constant of silicon, V = potential difference across the region; q = electronic charge; N = concentration of ionized impurity centers (5).

In a diffused junction like that of Fig. 2 the density of impurity centers is such that the depletion region in the p-type silicon is typically 1,000 times as thick as the one in the n-type silicon. The thickness ratio is approximately $X_p/X_n = (\sigma_n/\sigma_p)^{1/2}$ (σ's are conductivities). Thus most of the depletion region is in the p-type material beyond the junction.

For best performance the detector should be designed so that a charged particle loses all of its energy in the depletion region, which should approach the physical depth of the silicon slab. In practice the thickness of the depletion region is limited by the voltage that can be applied. Ideally the limit would be set by the breakdown potential of the material, but it is usually set by leakage currents across the surface.

The effective capacitance of the junction as a charge collector is established by the width of the depletion region and is $C_d = \epsilon/4\pi X$. From the expression for X, one can see that the capacitance is inversely proportional to the square root of the collection voltage or bias. In the depletion region there is an electric field with a maximum given roughly by $E_{max} = (8\pi qNV/\epsilon)^{1/2}$. A representative value of E_{max} is 10^4 volts/cm.

Detection and Spectrometry

A charged particle incident on the face of the detector produces hole-electron pairs in the semiconductor. The intense electric field promptly sweeps apart the charge carriers in the depletion region. Charge carriers produced outside the depletion region may diffuse to the depletion region and be swept across the junction if their lifetime is long enough.

Collection of the charges produces a voltage pulse with a magnitude proportional to the number of carriers that

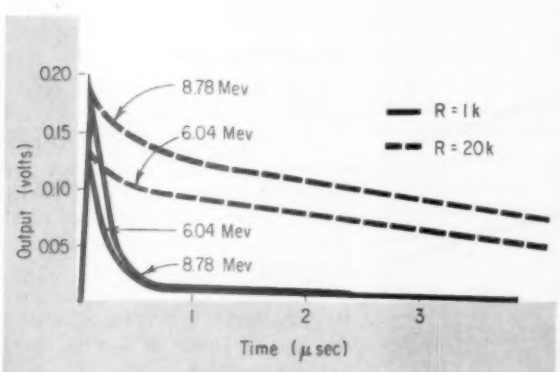


FIG. 4. PULSE DECAY times are limited by external electronics when large bias creates thick depletion region

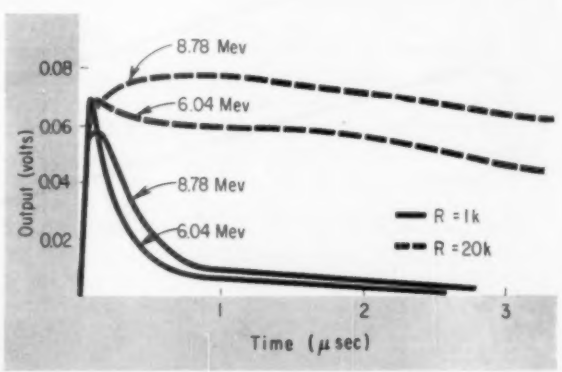


FIG. 5. SPEED OF RESPONSE is demonstrated by observing pulses with two load resistors and small bias

have crossed the junction. Because of the inherent difference between the rate of charge drift under potential gradient and the rate of diffusion under a concentration gradient, the resulting voltage pulse has two components: the hole-electron pairs formed in the depletion region produce an extremely fast rising pulse; pairs produced elsewhere, if they live long enough to diffuse into the depletion region, add a slow component.

Performance

D-C current-voltage characteristics of two detectors are shown in Fig. 3; biasing arrangement is indicated in Fig. 2. The difference in the breakdown voltage is attributed to the variation of surface conditions obtained in the fabrication processes.

Figure 4 shows the response of the detector to alpha particles with ranges less than the width of the depletion region. Rise time ($<3.5 \times 10^{-9}$ sec) is limited by the response of the electronic system used rather than that of the detector. Decay, also, is characteristic of the RC constants of the electronics as indicated by its change with the value of the load resistor.

Voltage response to alpha particles penetrating beyond the depletion region shows the effect of the longer collection time due to the diffusion of carriers to the depletion region (Fig. 5). With a 1,000-ohm load resistor, pulse height from 6.04-Mev alpha particles is greater than that from 8.78-Mev alpha particles. This is because the high energy alpha particles lose a smaller amount of energy in the depletion region than do the low-energy ones, and circuit integration time is too short for carriers formed outside the depletion region to diffuse into it in time to contribute to the fast portion of the pulse.

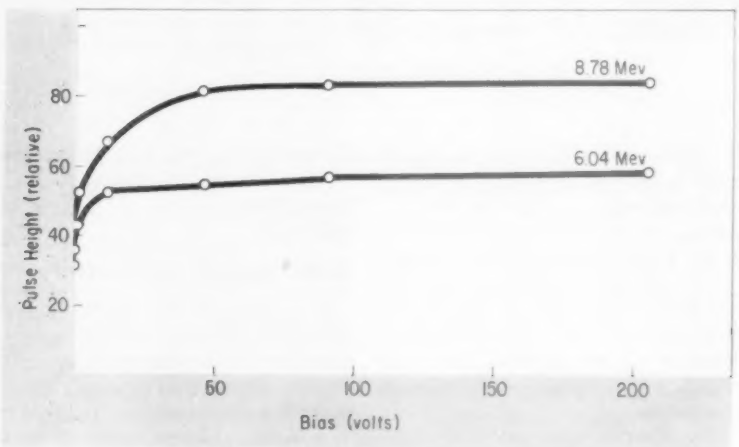


FIG. 6. PULSE-HEIGHT CHANGE shows that increasing bias increases sensitive volume of detector exposed to alpha particles of two energies

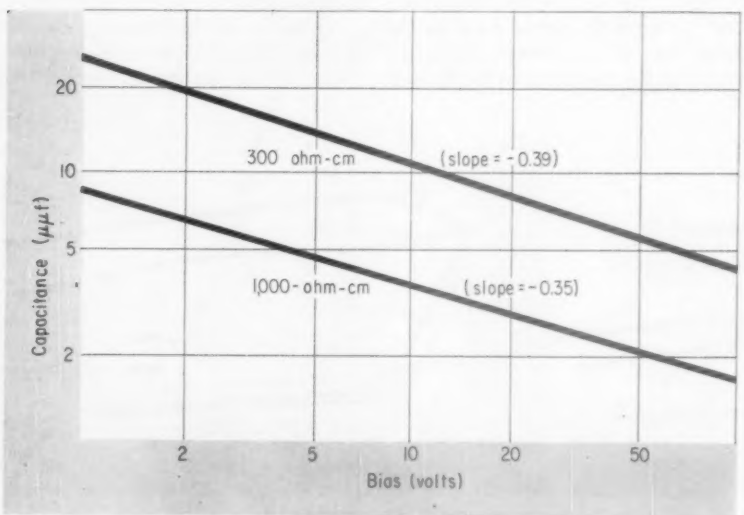


FIG. 7. JUNCTION CAPACITANCE decreases as bias increases

Pulse Height and Bias

The relation between pulse height and bias is shown in Fig. 6. At least two factors contribute: capacitance decreases with bias and this increases pulse height, and thickness of the depletion region increases with bias.

The influence of capacitance is simply computed. The pulse height can be written as $P = Q/(C_a + C_d)$ (Q = total charge in pulse, C_a = input capacitance of amplifier). From this we expect pulse height to increase continuously with increasing bias. However, small-area detectors with large base resistivity have a capacitance that is negligible as compared with C_a for all biases greater than a few volts. Figure 7 is a log log plot of capacitance as a function of bias. The equations for X and C_d imply that the slopes of these curves should be -0.5. The deviation from theory is attributed to the nature of the diffused junction and the detector geometry.

Figure 6 shows that the bias required for signal saturation is higher for higher-energy alpha particles. This is explained in terms of the longer range of the 8.78 Mev alpha particles; a thicker depletion region must be created before all of the energy of the higher-energy particle is deposited in it. If the bias is large enough that $C_a \gg C_d$ and the depletion region is thicker than the particle range, pulse height does not increase with bias.

Linear Response

With proper fabrication and biasing, the detector has a linear response over a wide range of energies. The range of particle energies over which pulse height is proportional to particle energy depends on the range of the particle and its relation to both position and thickness of the depletion region.

The first of two main requirements for proportionality between pulse height and particle energy is that the energy lost in the region between the surface of the detector and the depletion region

(Continuhd on p. 58)

Putting Semiconductor Detectors to Work

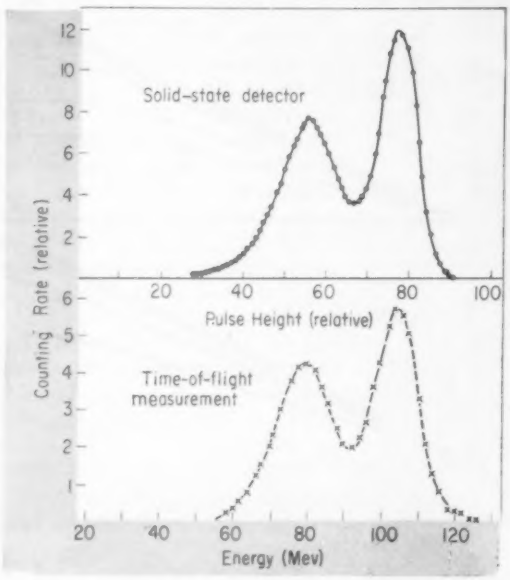


FIG. A. FISSION SPECTRUM of Cf^{252} by two methods

FIG. B. SMALL MONITOR has counting rate of 6×10^7 cpm limited by electronics, not dead time

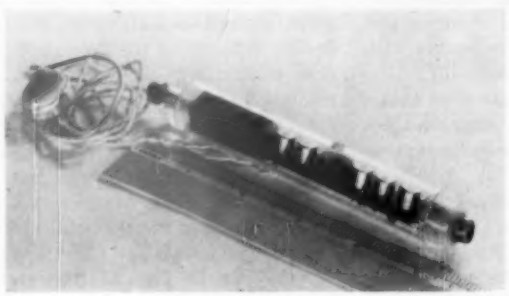


FIG. C. "ALPHA CIGAR" uses junction detector to make small, rugged, portable survey instrument

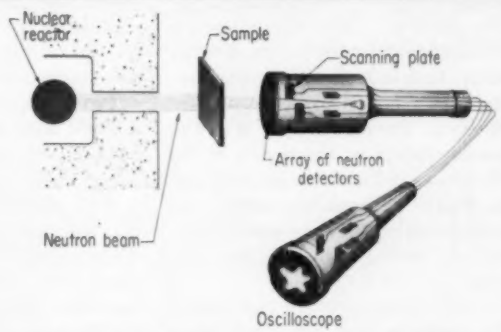


FIG. D. NEUTRON ICONOSCOPE with detector array

The semiconductor detectors described in these pages have already been used for some useful and interesting measurements in particle physics.

For survey instruments they offer the advantages of ruggedness and small size. Not only are they small themselves, but the absence of thin windows, gas flow tubes, phototubes and high-voltage supplies makes their volume requirements small.

Particle physics. Figure A shows the spontaneous-fission spectrum of Cf^{252} as measured by a group at Berkeley using these detectors and another measurement by time-of-flight methods (*7*). The shift in energy spectrum is explained by the loss of fission-fragment energy in the region between the surface and the beginning of the depletion region. Work continues to produce junctions and depletion regions that are closer to the surface to improve this limit.

Neutrons. It is apparent that detection of neutrons is feasible by depositing B^{10}, fissionable nuclides or hydrogen-containing material on or near the detector surface. Materials with a threshold response can be used to indicate neutron energy (*8*). The detectors are small enough that they will not perturb most neutron spectra.

Alpha survey. A palm-size picket survey instrument is shown in Fig. B and an "alpha cigar" with an audible counting rate in Fig. C. Counting rate is limited only by electronic circuitry, not by detector dead time. The survey meter of Fig. B operates at rates up to 6×10^7 cpm.

Beta detection. Signals from beta particles have been obtained by making high-resistivity detectors and applying large biases. At this writing a 1,000-ohm-cm detector with 120-volt bias yields measurable pulses with P^{32} and Tl^{204} betas.

Gamma photons. At present the detectors do not respond to individual photons. However, the change in d-c current in an intense gamma field is recognizeable. As yet the effect of gamma radiation on the operation of the junctions as charged-particle detectors has not been evaluated.

Future Possibilities

There are many future applications that exploit the smallness of the detectors. For example, Fig. D shows a neutron iconoscope. A sample would be placed in a neutron beam, and the neutron transmission would be recorded by a two-dimensional array of detectors.

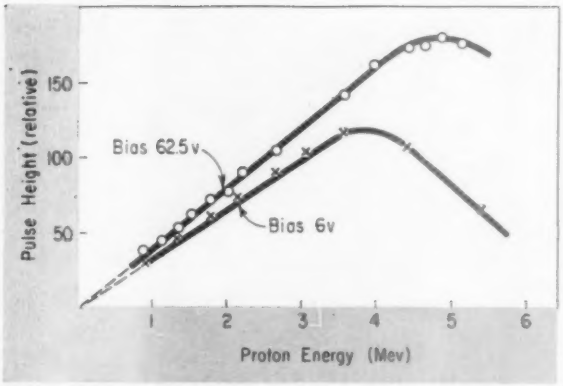


FIG. 8. LINEARITY exists in pulse-height–energy relationship for protons that do not penetrate beyond depletion region

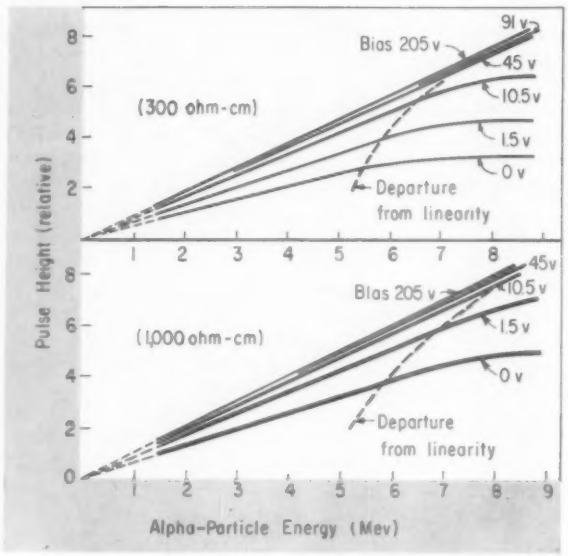


FIG. 9. ALPHA-PARTICLE PULSES are proportional to energy over greater range if resistivity and bias are large

be a small fraction of the total energy of the particle. (This requirement is particularly important for short-range particles such as fission fragments, low-energy protons and low-energy alpha particles.) The high density of recombination centers in the region of the phosphorous diffusion means that carriers created between the surface and the depletion region have small probability of moving into the depletion region.

For high-energy protons, high-energy alpha particles and beta particles a second criterion is more important. This is that the depletion region have a thickness greater than the particle range. The equation for depletion thickness X shows that it is proportional to the square root of resistivity and the square root of applied voltage. Thus large base resistivity is indicated for deeply penetrating particles.

Figure 8 shows variation of pulse height with proton energy for two biases. Greater bias leads to smaller capacitance, larger signal and a greater range of linear response. Pulse height falls off rapidly with increasing energy because the more energetic particles penetrate beyond the depletion region and experience the greatest energy loss at the ends of their paths.

Figure 9 shows pulse height as a function of alpha-particle energy and bias for 300-ohm-cm and 1,000-ohm-cm detectors. The marked improvement resulting from the use of higher resistivity material can be seen by comparing the two sets of curves and also by comparing these curves with previously published results (*6*).

Figure 9 and other data show that a diffused layer less than 1 micron thick has negligible effect on response to low-energy alpha particles.

With 45-volt bias and a 1,000-ohm-cm detector we have measured a linear response down to 0.3 Mev. The effect of a thicker diffusion region is apparent from Fig. 10, obtained with a diffused junction 12 microns below the surface. The effect of recombination in the diffusion region is apparent; the detector does not respond to particles penetrating less than 12 microns.

Resolution

From the response of the junction to injected charge, the resolution appears to be limited by the noise level of the amplifier system. However, all the factors influencing the resolution are not understood. The variation of resolution as a function of reverse bias for 5.5-Mev Am^{241} alphas is shown in Fig. 11. The poorer resolution at low bias is due in part to the decrease in pulse height, which causes the finite channel width of the electronic system to become limiting.

As shown in Fig. 12, the energy resolution (full width at half maximum over pulse voltage) is presently 0.6% for 5.3-Mev alpha particles.

Energy resolution is also limited by source-detector collimation. As the source-to-detector separation becomes greater, paths of particles entering the detector are more nearly parallel and energy deposition is more nearly uniform. Fig. 13 shows the effects of both collimation and bias. When bias

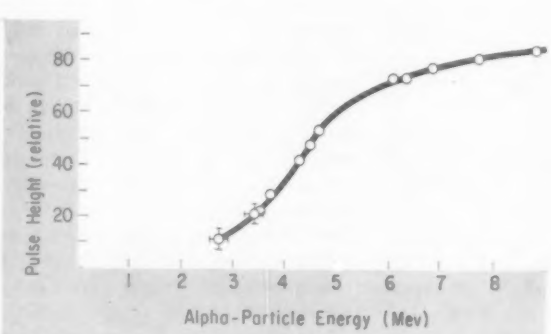


FIG. 10. DEEPER JUNCTION produces nonlinear response. Here *p-n* junction is 12 microns inside material

is 10.5 volts, deviation from linearity occurs at ~6.5-Mev. Thus the range of an 8.78-Mev alpha particle is greater than the thickness of the depletion region, and that of a 6.04-Mev alpha is less than that thickness. This accounts for the spread of the 8.78-Mev peak when the source is ½ in. from the detector; some particles are incident at an angle, lose more of their energy in the depletion region and thus produce larger pulses than those that come straight in.

From the resolution discussed, it should be anticipated that 50 kev represents the lower limit of resolution. Preliminary measurements, with 400-kev protons, however, point to a lower limit of 25 kev. Alphas with an energy of 100 kev have been detected but insufficient data has been obtained to warrant further comment.

* * *

We wish to acknowledge the assistance of George Kilian, Harry Bowman, M. Luis Muga and Stanley G. Thompson of the University of California, Berkeley, for obtaining Cf^{252} data and for sources for the high-resolution data. Thanks are due to C. S. Wu and Paul Simms of Columbia University for the use of their accelerators and help in obtaining the proton data, and to C. A. Barnes and his graduate students at the California Institute of Technology for supplying information on low-energy protons and alpha particles.

Thanks are due to the group at the Hughes Aircraft Co., consisting of: H. Dunlap, R. J. Grainger, G. Kramer, L. E. Nealy, J. W. Oliver, R. M. Olson, C. T. Raymo, H. E. Scarlett, L. S. Senhouse, G. W. Simon and J. R. Underwood, for their enthusiasm and cooperation and finally to F. Keywell and J. M. Denney for their assistance in the early stages of this work.

We are indebted to the Defense Atomic Support Agency for partial support of this work.

BIBLIOGRAPHY

1. K. G. McKay, *Phys. Rev.* **84,** 829 (1951)
2. J. W. Mayer, B. R. Gossick, *Rev. Sci. Instr.* **27,** 407 (1956)
3. F. J. Walter, J. W. T. Dabbs, L. D. Roberts, H. W. Wright, ORNL 58-11-99 (1958)
4. J. M. McKenzie, D. A. Bromley, *Phys. Rev. Letters* **2,** 303 (1959)
5. R. D. Middlebrook, "An Introduction to Junction Transistor Theory," pp. 160–170 (John Wiley and Sons, 1957)
6. S. S. Friedland et al., *Rev. Sci. Instr.* **31,** 74, (1960)
7. J. C. D. Milton, J. S. Fraser, *Phys. Rev.* **111,** 87 (1958)
8. J. B. Trice, NUCLEONICS **16,** No. 7, 81 (1958); R. Rochlin, NUCLEONICS **17,** No. 1, 54 (1959)
9. U. Facchini, A. Malvicini, NUCLEONICS **14,** No. 5, 96 (1956)

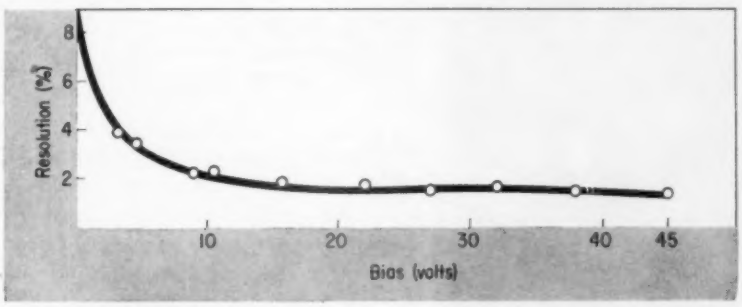


FIG. 11. RESOLUTION IMPROVES with increasing bias mainly because of finite channel widths in analyzer

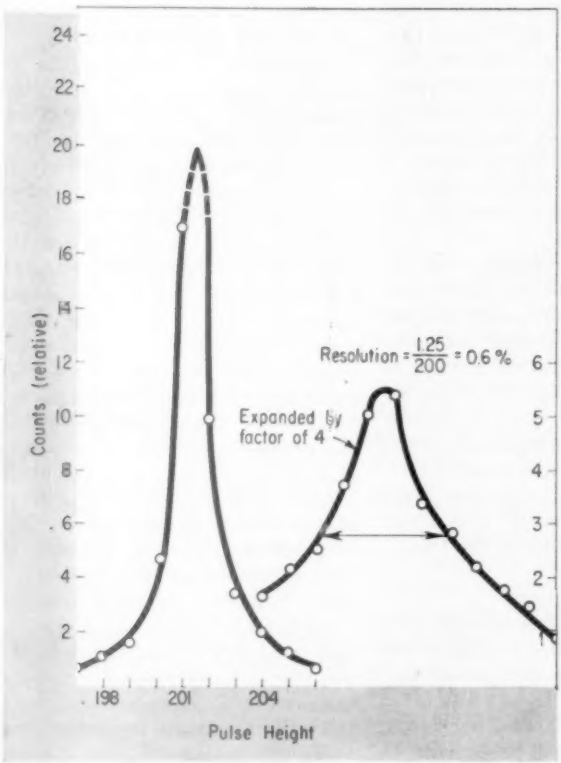


FIG. 12. ENERGY RESOLUTION for 5.3-Mev alpha particles is 0.6% in 300-ohm-cm detector with 6-volt bias. Expanded scale provides detailed picture of peak

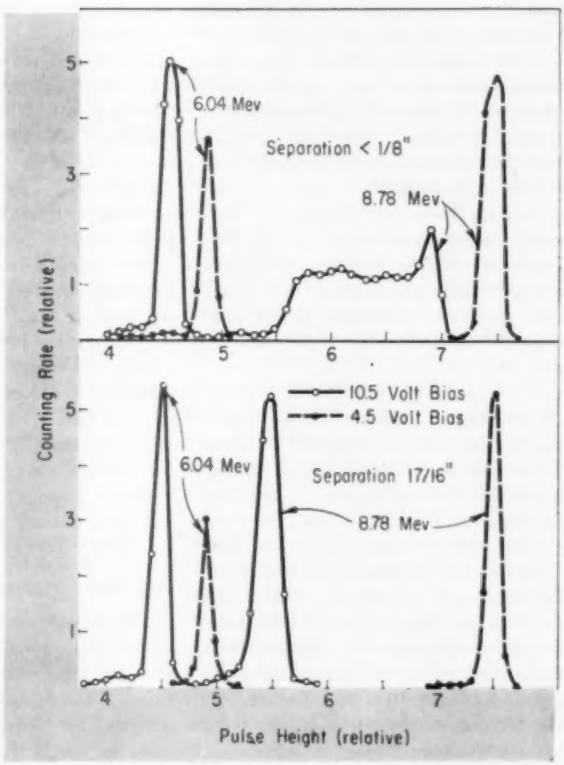
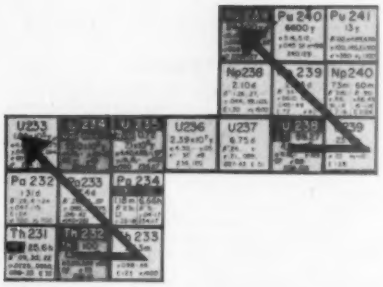


FIG. 13. COLLIMATION improves resolution. Source-detector separation and bias were changed as 300-ohm-cm detector responded to alpha particles of two energies from Pb^{213}



Breeding—How

"... Perhaps within 40 Years—But We Must Start Now"

By W. K. ERGEN
Oak Ridge National Laboratory
Oak Ridge, Tennessee

William K. Ergen, a reactor physicist at ORNL (home of liquid-fuel breeders), argues that, on the basis of our known ore reserves, breeders might be justified before year 2000. To have them ready for use then, we have to pursue development now.

THE NEED for breeder reactors depends strongly on the period of time under consideration. For the next few years, enough fissionable material is clearly available to operate all the reactors contemplated without breeding. In the next few decades, breeding could well become economically desirable, although perhaps not necessary if low-grade ores are considered. In the next centuries, breeder reactors will most likely become the main source of the vast amounts of energy required to maintain a reasonably high standard of living.

We do not wish to overstate the case for breeding. In the first place, breeding per se, that is, the production of fissionable materials in excess of consumption, is not enough. Breeding must be combined with low inventory per kilowatt; in other words, the doubling time of the reactor must be short. In the expanding economy of the next decades the doubling time of the reactors must be as short as or shorter than the doubling time of the nuclear power demand (about 10 years). Otherwise the high inventory requirements bring about a shortage of fissionable material, whether the reactors breed or not. This has been discussed in great detail by Arnold and Ullmann (*1*).

Second, even should we fail to develop breeders by the time the rich ores are exhausted, we could fall back on the vast amount of poorer ores, the 6,000,000 tons from which U_3O_8 can be extracted at \$30–50/lb, or the still larger reserve of ore requiring in excess of \$50/lb U_3O_8. This would increase the cost of power, but the wheels would not grind to a standstill.

However, fission energy, derived from ores recoverable at about the current prices, will substantially exceed our energy reserves derived from conventional sources only if breeding is available. The necessity for breeding on this basis might occur within the next 40 years, that is, within the period for which planning today is imperative.

Hence, breeders with low inventory, or short doubling time, are a valid goal for reactor development at this time.

The Next Years

The immediate future is largely concerned with producing nuclear power at costs competitive with present-day prices. Consumption of fissionable material for power production during the next few years will be too small to necessitate the use of higher-priced raw materials.

The fuel-burnup cost in a straight burner, at present prices, is about 3 mills/kwh. Thus a difference of 10% in conversion ratio amounts to about 0.3 mill/kwh, since a reactor of conversion ratio β could buy fuel amounting to 10% of its burnup for 0.3 mill/kwh and end up with the same amount of fissionable material as a reactor of breeding ratio $\beta + 0.1$. A breeder and a converter* of reasonably high conversion ratio will not differ in conversion ratio by more than a small multiple of 10%, and the difference in fuel-burnup cost will thus be smaller than the uncertainty in the estimated power cost of a nuclear reactor. Hence, fuel-burnup cost based on present prices does not offer a strong motive for breeding.

Justification for breeding thus involves planning ahead to the time when fissionable material recoverable at reasonable cost will be exhausted and the nuclear-power economy will have to depend on tapping the energy content of fertile material. The justification of breeding, then, is analogous to the justification of nuclear-power production in general—we pursue nuclear power now because of the foreseeable depletion of fossil fuel rather than because of present prices. Long-range planning is needed in the nuclear-power field because of the long development and design time (about 15 years) and long life of power plants (about 25 years). Thus, if breeding will be necessary $15 + 25 = 40$ years hence, that is, by about the year 2000, it is not too early to proceed with the development now. Otherwise we shall have, 40 years hence, a large installed capacity that could still be used except for the fact that it burns fissionable material that we can no longer afford to burn. If it is the intention to scrap these reac-

(Continued on page 62)

* In this connection, any reactor that produces less fissionable material than it consumes is called a converter.

Soon a Necessity?

" . . . About a Century Away—Costs Come First"

By E. L. ZEBROSKI
Atomic Power Equipment Dept.
General Electric Co.
San Jose, California

E. L. Zebroski, engineering consultant at GE-APED (which besides its BWR's is also looking at a fast oxide reactor), argues that low-cost fuel for converters will be ample for about 100 years—breeder development is desirable but should now aim at costs rather than conservation.

PROJECTIONS of future patterns of discovery, technology of utilization and demand for energy resources are, at best, a kind of informed speculation. Such speculation is unavoidable, however, in any plan for the development of our energy sources. More quantitative information on nuclear fuel resources and costs has recently become available which permits the following interesting conclusions on the probable timing and relative future roles of converter reactors, breeder reactors and fuel recycle:

- We can operate converter-type reactors on our domestic uranium reserves alone for at least 50 years before depletion of known domestic ores would start to have a small effect on power costs.
- There will be no pinch in fuel supply or costs if we introduce fuel recycle, improved converters and breeders on the schedule shown in Table 1. Economic reliable breeders types are desirable—but also difficult—to develop. There is both time and incentive to develop reactors capable of breeding for their economic potential.

TABLE 1—Reactor Stages

System	*% reduction in ore demand*	*When large scale plants needed*
Converter reactor	(ref. level)	in 10–15 years
Pu or U^{233} recycle	~50	in 30–50 years
Improved converters (conversion ratios ≈ 1.0)	70–80	in 50–80 years
Breeders (conversion ratios > 1.0)	80–95	~100–200 years

- Earlier development of each stage in Table 1 is desirable but large scale use will be governed by whether or not it can compete economically with the previous stages in areas other than burnup costs (e.g., capital, maintenance, and fuel-fabrication costs).

These conclusions were reached by first establishing an estimated nuclear-power-demand for the future and then from this calculating the uranium supply needed to satisfy that cumulative demand (assuming a typical burner-reactor design). By relating this supply curve to estimates of the actual uranium-ore reserves of various grades in the U. S., it is possible to estimate the potential economic effect of each step.

Energy Demand Projections

Figure 1 shows a typical projection of total electric-power demand and a projection of "probable" nuclear-power demand. The total electric-power demand for 1955–1980 is based on Federal Power Commission estimates (*3*).

The final rate shown rests on the observations that (a) over-all energy use has been rising by about this average rate for the last 40 years, and (b) electric power is not likely to exceed half of the total energy consumption at the end of this period, even with far-reaching changes in the direction of electrification (*2, 4*). Rather than base this long-term projection on an exponential growth pattern with a constant exponent (which leads to absurdities), we have adopted the pattern of growth found in the liquid-fuel and automobile industries—an initial period of several decades of growth (often closely exponential) much more rapid than the growth of the gross national product, followed by growth more nearly proportional to that of the gross national product.

Figure 2 shows a more rapid growth projection which is an extension of a trend intermediate between Series I and Series II of the McKinney Panel. This can be taken as the "maximum plausible" trend, since it rises more rapidly and equals or exceeds projections of total electrical power demand by the year 2000.

Since uranium is an extremely abundant resource, depletion of low-cost reserves will not even come into view until near-future uranium consumption rate increases several hundredfold. The course of demand during the early exponential growth is almost irrelevant to the question of conservation; the

"Perhaps Within 40 Years . . ."—ERGEN

tors before they are worn out, they would have to be burdened by larger depreciation costs during their use.

The Next Decades

If we look to the next 40 years, say, the availability of raw materials does begin to become an important factor. The available nuclear raw material can be compared with two other quantities: the raw material available for non-nuclear-power production and the demand for nuclear-power raw material.

If we confine ourselves to the U. S., an AEC staff paper (*2*) reports that in the U. S. 230,000 tons of U_3O_8 is known to be recoverable at approximately the present cost of \$10/lb U_3O_8; to this, 350,000 tons should be added on the basis of specific geological evidence in the areas known to contain deposits. This gives a total of 580,000 tons. Known reserves in the U. S. recoverable at \$30–50/lb U_3O_8 are 6,000,000 tons. In addition, there are large reserves recoverable at \$50 or more per pound of U_3O_8.

Let us compare the reserves of nuclear fuel with those of conventional fuel in terms of energy content per ton. The energy content of 1 ton of U_3O_8, if all the uranium is used, amounts to 5.9×10^{13} Btu. If only the U^{235} is burned, the energy content of 1 ton of U_3O_8 would be 3.6×10^{11} Btu, taking into account that, for every U^{235} fission, 0.18 of a U^{235} atom is lost by radiative capture. Thus, 580,000 tons of reasonably certain U. S. reserves of high-grade ore would amount to 34×10^{15} Btu, or 0.21×10^{15} Btu, depending on whether all of the uranium, or only the U^{235}, is burned.

For comparison, the U. S. reserves of oil and gas recoverable at up to 1.3 times the present cost, plus the U. S. reserves of other fossil fuels recoverable at up to twice the present cost, amount to 6.9×10^{15} Btu (*3*). At these prices of fossil fuel, nuclear power is believed to become competitive. Thus, at least 20% of the U^{238} has to be burned before the uranium recoverable at today's prices contributes as much to the energy reserves of the U. S. as the fossil fuels. Burning 20% of the U^{238} requires an average conversion ratio of 96.4%.

Hence, the nuclear-energy reserves will exceed the fossil reserves only if conversion ratios in excess of 96.4% are obtained. Breeding requires conversion ratios of 100% or more. Although the higher the conversion ratio the more difficult it is to increase the conversion ratio, it would not appear much harder to achieve breeding (conversion ratio = 100%) than a conversion ratio of 96.4%.

There are applications of nuclear energy other than civilian power production which burn fissionable material without being able to pay attention to high conversion ratio or to breeding. Examples are nuclear-powered ships, aircraft, rockets and weapons. Most likely more than 3.6% of the fissionable material will be used in straight burners (weapons would also fall in this classification). Hence, the conversion ratio of the civilian power producers will have to be greater than 100%; that is, the civilian power producers will have to be breeders if nuclear-energy reserves are to exceed fossil reserves. The numerical values depend somewhat on the ground rules used (as stated above), but qualitatively the results remain the same under somewhat different rules.

Any statement that nuclear power can tap energy reserves far in excess of those available from fossil fuels clearly implies the use of breeders.

We can also compare the supply of nuclear-energy reserves with the estimated demand for nuclear-power production. Of course, these estimates vary considerably, as indicated in the table, which gives the nuclear-power production in 1980 and 2000, as well as the doubling time of the nuclear-power demand between 1980 and 2000. The 1980 estimates were taken from a table in NUCLEONICS (*4*), the "minimum" being the J. A. Lane estimate, the "average" the arithmetic mean of the McKinney report estimates, and the "maximum" the Davis and Roddis estimate. These "minimum," "average" and "maximum" estimates (given in the NUCLEONICS table only up to 1980) were plotted and extrapolated in an admittedly somewhat arbitrary manner to the year 2000.

If the power demand is satisfied by reactors with a conversion ratio of 1.00, that is, by reactors that just barely miss being breeders, there is no consumption of fissionable material by burnup. The demand for fissionable material comes solely from inventory requirements. Based upon the 580,000 tons of U_3O_8 quoted above and 100%

"About a Century Away . . ."—ZEBROSKI

depletion of the reserves *already known today* will not come into question until *after* the period of rapid growth.

Taking the nuclear-power-demand curve, we can determine the annual fuel throughput, inventory requirement and cumulative requirement for an economy of converter reactors.

The typical reactor characteristics we assume (see Table 2) are generally similar to recent water-moderated-reactor designs (*16*), except for a 5% increase in thermal efficiency and 20% higher over-all specific power. (Over-all specific power refers to total inventory, in-pile plus out-of-pile.) These increases are consistent with the expected results of development now under way, are probably conservative for plants built after 1970 and almost certainly underestimate the performance of plants built 25–50 years from now.

From a resources standpoint (although not from a power-cost standpoint) we can regard all present converter reactor types as roughly equivalent. Inventory requirements differ by a factor of no more than 2, and cumulative throughput by less than 50% in terms of equivalent consumption of natural uranium for all the common current reactor designs, including gas-, sodium- or organic-cooled converter reactors. This applies to either graphite or heavy-water moderators and to either natural or slightly enriched uranium fuel. The consumption of natural uranium for inventory and throughput is shown in Fig. 3, calculated from the characteristics given in Table 2 and the "probable" power-growth curve in Fig. 1.

Recycling. A converter reactor can reduce its requirements of natural uranium by recycling the plutonium (or U^{233}) produced. The right-hand column of Table 2 gives the characteristics of a reactor with plutonium and uranium recycle.

Although there is no *immediate* economic incentive for recycle in the U. S., in estimating the *long-term* demands of

recovery of the contained U^{235}, the following inventories of fissionable material per electrical megawatt produced would be permissible:

Nuclear-power-demand estimate	Permissible inventory [kg/Mw(e)] 1980	2000
Minimum	75	19
Average	34	4.3
Maximum	14	1.06

The estimates of the fuel inventory run between 1 and 10 kg/Mw(e) for future reactors. If a fair fraction of the U. S. uranium supply is used for other purposes than power production and if the highest estimates of power demand and the highest fuel inventory are found to apply, breeding may become a necessity by 1980. For the lowest estimates of nuclear-power demand, breeding will be unnecessary until sometime past the year 2000; in fact, low-inventory reactors could get by without breeding until 2000 even for the highest power-demand estimates.

Unfortunately, that leaves unanswered the question whether breeding will be a necessity within the next 40 years and, hence, whether breeder development now is timely. The only thing that can be said is that there is a strong possibility that this will be the case, and that breeder development should be pursued as insurance against this possibility.

The Next Centuries

The prospects of the energy requirements in the distant future were the subject of a recent paper by Weinberg (*5*). Weinberg considers the time—actually quite a few centuries in the future—when all concentrated sources of fuel are used up and humanity has to depend on the average granite, the sea and the sun for its energy supply. The solar energy, because of its dilute character, appears useful only for special purposes, such as space heating and raising food. The idea that the sea contains practically inexhaustible energy reserves, *if* the deuterium in the sea water can be "burned" in nuclear fusion, has received wide publicity.

The point made by Weinberg in his paper deserves to be re-emphasized—the average rock of the earth's crust constitutes an energy reserve about as large as the sea because of its content of uranium and thorium. By weight, there are 32 ppm of deuterium in the sea water and 16 ppm of uranium and thorium in the earth's crust. If 1 g of deuterium is burned to He^3, He^4, H and neutrons, 1 Mwd of heat is generated—the same amount generated by fissioning 1 g of uranium or thorium.

Of course not all the deuterium in the sea, nor all the uranium and thorium in the rocks, can be extracted. According to Brown and Silver (*6*) about one-fifth of the uranium and thorium is contained in the rather easily leachable portions of granites, and the energy content of this portion is equivalent to 3,000 kwd of heat per ton of granite. It takes about 0.8–1.5 kwd to process a ton of granite.

Thus, the energy content of the fissionable and fertile materials in granite is vastly greater than the energy required to extract it. However, the fissionable material, U^{235}, which is only 1/400 or 1/500 of the total uranium-plus-thorium content, contains only 6–7.5 kwd/ton of rock. At the present efficiency of converting nuclear energy into the electrical or mechanical energy required to process the rock, humanity could hardly live on granite if burners that use only the U^{235} were the only reactors available. Breeders, which use all the uranium and thorium, would make ordinary granite an attractive energy reserve—in fact, in comparing sun, sea and rock as ultimate energy sources, the rock appears to be the most realistic one, by far.

Nuclear Power Demand

	Installed capacity [10^3 Mw(e)] 1980	2000	Doubling time (years)
Minimum	42	168	10
Average	93	740	6.7
Maximum	227	3,000	5.4

BIBLIOGRAPHY

1. E. D. Arnold, J. W. Ullmann. Use of raw materials in an expanding nuclear power economy, ORNL-2698 (Apr. 2, 1959)
2. Uranium and thorium raw materials supplies (Division of Raw Materials, USAEC, October, 1958)
3. P. C. Putnam, "Energy in the Future" (D. Van Nostrand Co., Inc., Princeton, N. J., 1953)
4. NUCLEONICS **15**, No. 4, 18 (1957)
5. A. M. Weinberg. Energy as an ultimate raw material, presented before the Southeastern Section of the American Physical Society, New Orleans, Apr. 10, 1959
6. H. Brown, L. T. Silver. "International Conference on the Peaceful Uses of Atomic Energy," vol. 8, p. 850 (United Nations, New York, 1956)

a converter-reactor economy on uranium supplies, we assume that recycle is used. There is an economic incentive for recycle when fuel throughput becomes large, or if ore-concentrate costs rise appreciably. Figure 3 also shows annual throughput and cumulative demand with recycle of plutonium to reactor fuel and uranium to isotope separation plant.

Effect of Fuel Reserves

The "probable" growth rate projected in Fig. 1 implies a cumulative requirement of the order of ½-million tons of natural uranium 50–60 years from now,* rising to 2–3 million tons in 100 years. For the maximum growth rate (Fig. 2), the 1-million-ton level is reached by the year *2010* and the 5-million-ton level by *2035*. This demand projection is conservative (high) since it neglects the expected increase in average conversion ratio.

The published picture on uranium reserves in the U. S. can be summarized as follows (*7, 8*):

- A total of "proven reserves" (Table 3) plus "inferred" reserves and reserves "indicated from specific geologic evidence" of about 500–600 thousand tons recoverable at $10/lb (as U_3O_8) or less.
- Known low-grade reserves of 5–6 million tons recoverable at costs of $30–$50/lb with present technology (*19*).
- Larger reserves of very-low-grade material recoverable at >$50/lb (at present costs).

The reserves picture is not likely to remain static.

Estimates of the "ultimate reserves" in the petroleum industry have tended to rise in proportion to the total production, exploration and reserves discovered up to the time of the estimate (*10*). Eventually, of course, depletion of a particular reserve at a given cost will occur.

The first two categories above seem to constitute a finite domestic reserve of "low-cost" fuel. It seems necessary only to agree on an exponential growth pattern and *assume no further imports,*

* With U and Pu recycle, or about 15–20 years earlier with U recycle alone.

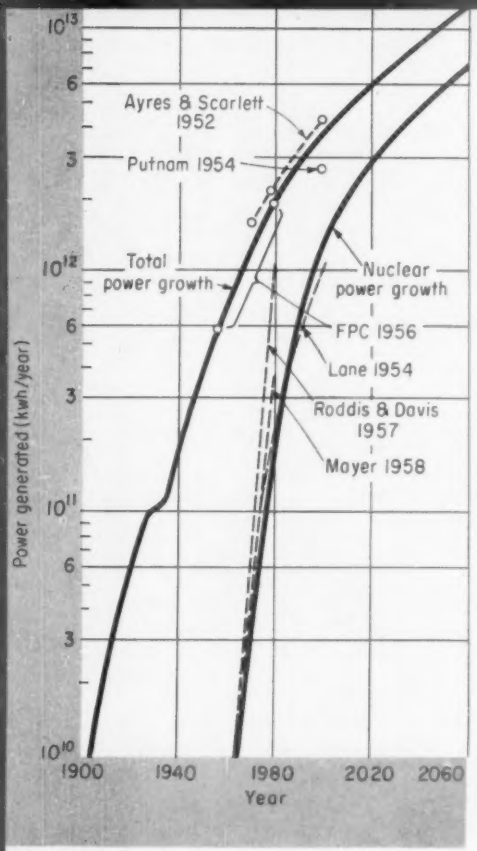
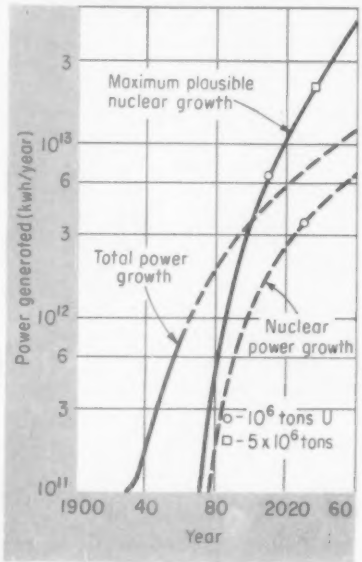


FIG. 1. PROJECTIONS of probable growths in U. S. of total electric power and nuclear power over next 100 years

FIG. 2. MAXIMUM PLAUSIBLE GROWTH compared with probable curves in Fig. 1. Tons U refers to cumulative demand to specified date



discovery or improvement in recovery methods to determine how soon the reserve is committed. Even on this unrealistic basis there is a 50–100 year supply in the known reserves.

But beyond this the trend in discovery of uranium reserves over the last 10 years, as well as the history of oil-reserve estimates, indicates that the present estimates for low-cost uranium reserves are very probably low.

U. S. ore reserves have risen from under 1 million tons in 1948 to nearly 90 million tons in 1959 (see Table 3). During the period of intensive large-scale exploration (1951–1956), the known high-grade-ore reserves grew exponentially, doubling every 11 months (*20*). Despite the discouraging short-term outlook for the uranium market since 1956 and curtailment of prospecting, net reserves have further increased by 50%.

If we take into account the trend in discovery and reserves of uranium and assume a long-term pattern similar to that for oil, we can construct a plausible, semiquantitative view of the "ultimate" reserves available. Figure 4 shows a relation between millions of tons of uranium recoverable and the cost of recovery. The lower limit of the shaded region is derived by assuming that a twofold increase in actual recovery will be experienced beyond present "ultimate-reserves" estimates (*7*). The upper limit in this region is derived by analogy with the experience with oil, where the "estimated ultimate reserve" has increased 5–10-fold in the last 40 years. In the region of $300–$1,000/lb uranium, Brown and Silver have observed that various granites become a very large source—even though they contain only 10–20 ppm of uranium, only one-fourth to one-third of which can be easily leached out (*12*).

Assuming that 0.01–0.1% of the earth's surface can be mined this way, *reserves exceeding 1,000 times the cumulative requirement estimated for the next 100 years* are predicted. The upper limits of possible recovery at a given cost should also allow for possible changes in the technology and economics of recovery. There is also prospect that igneous rocks with higher uranium contents may be common. Also, in the treatment of granite, by-product values from other constituents may be significant. About three times as much thorium is recoverable as uranium, suggesting that when very low-grade reserves need to be tapped—if not sooner—thorium will be a major fertile material.

It should be recognized that the estimates of ultimate resources shown in Fig. 4, which are several-fold greater than the present estimates by AEC geologists, are not made on geological grounds. They rest rather on the observation that the pattern of discovery and recovery implies a high probability that the estimates of ultimate reserves will increase with further exploration. The *implausible* combination of assumptions—now common in the nuclear-energy literature—is one in which power consumption and demand for raw material grow exponentially forever but resources and recovery technology are fixed to the estimates of a given date.

Even taking the maximum-demand curve in Fig. 2 we can conclude that a nuclear-power economy based entirely on converter reactors can continue to grow for about 50–60 years without noticeable change in the recovery cost of raw materials (about $10/lb in constant dollars) and for perhaps 100 years before feed costs rise to $20–$30/lb which would have only a minor effect on power costs.

Both Brown (*2*) and Putnam (*4*) see limitations in other resources which would tend to limit the rate of population growth beyond the next hundred

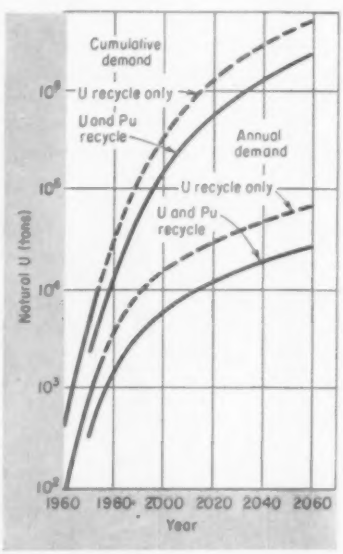


FIG. 3. THROUGHPUT AND INVENTORY needs for converter-reactor economy with U recycle or U-Pu recycle

TABLE 2—Converter-Reactor Characteristics*

	U recycle only	*U and Pu recycle*
Initial U^{235} enrichment, %	1.92	0.96
Final U^{235} enrichment, %	0.69	0.59
Plutonium discharge, %	0.63	(recycle)
Burnup, Mwd/ton fuel	15,000	10,000
Inventory, tons fuel†	$3.28 \times 10^{8}\ N_t$	$3.28 \times 10^{8}\ N_t$
Annual fuel throughput, tons fuel	$8.16 \times 10^{-9}\ N_{t-2}$	$1.22 \times 10^{-8}\ N_{t-2}$
Capacity, kw(e)	$1.43 \times 10^{-4}\ N_t$	$1.43 \times 10^{-4}\ N_t$
Tons natural U/ton fuel‡	2.54 (2.04)	0.78 (0.63)
Mwd/ton natural U‡	5,900 (7,350)	12,800 (15,900)

* See refs. *14* and *16* for details of reactor and fuel-cycle calculations.

† N_t = nuclear kwh/yr, t years after 1960.

‡ Figures refer to 0.22 % diffusion-plant waste-stream composition; numbers in parentheses refer to limiting value with 0.1 % in the waste stream. Since the reactor discharge is returned to the diffusion plant, the natural uranium requirement is related to reactor throughput rate by $F/P = (x_p - x_t)/(x_f - x_w) + f(x_t - x_w)/(x_f - x_w)$ where F/P = tons of natural uranium feed required/ton of reactor fuel and x_p, x_t, x_w and x_f are the fractions of U^{235} in reactor fuel, reactor discharge, diffusion plant discharge and diffusion plant feed respectively. (x_f = 0.0071 which excludes secondary feed x_t) f = fraction of uranium atoms destroyed or lost between diffusion plant output to the reactor and the depleted feed returned to the diffusion plant.

years and beyond a world population of 6–8 billion people. However, even assuming that power-demand growth continues at the rate shown in Fig. 1 for the years 2040–2060, it will be 200 years from now before total uranium demand pushes feed costs up to $30–$100/lb.

Effect of Natural-U Prices

The value of enriched uranium depends on the cost of natural-uranium feed and the cost of separative work [as determined by the theory of a diffusion cascade (*13*)]. Figure 5 shows the enriched-uranium price scale for three values of natural-uranium feed price.

The top curve corresponds to ore-concentrate costs of about $20/lb U_3O_8 as ore concentrate, which means a UF_6 feed cost of $27.30/lb of U content. This feed cost, about three times the near-future cost, can be expected to occur early in the 21st century when domestic reserves of present types of high-grade ore begin to become depleted, or about 20 years later if the current ratio of imports to domestic production is taken into account. Incremental supplies will then depend upon increased imports or the recovery of uranium from lower-grade ores such as phosphate rock and marine shales.

Figure 6 shows the effect of varying the cost of natural uranium on the depletion-cost part of fuel cycles for the converter reactor of Table 2. Similar trends can be expected for nearly all types of converter reactors.

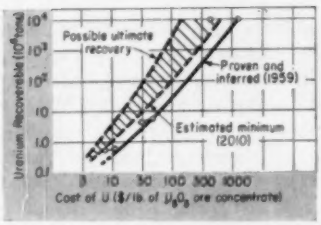

Possible ultimate recovery
Proven and inferred (1959)
Estimated minimum (2010)
Uranium Recoverable (10³ tons)
Cost of U ($/lb. of U₃O₈ ore concentrate)

FIG. 4. U. S. URANIUM RESERVES, known and projected, vs. recovery cost

With zirconium cladding, the gross burnup cost (difference in the value of the uranium before charging and after discharge) is increased by 0.8 mill/kwh when the cost of natural uranium is tripled from an anticipated low of about $6/lb to $20/lb U_3O_8. If we allow for Pu credit* the *net increase in fuel-cycle cost is only 0.4 mill/kwh.* (A similar reactor with stainless-steel-clad fuel would have a slightly poorer neutron economy and a higher initial enrichment. A similar increase in raw-material cost increases net fuel costs after credits by 0.6 mill/kwh.) With plutonium recycle, there is an increase of only about 0.25 mils/kwh over present depletion costs without recycle even if feed cost rises to $50/lb.

The significance of Fig. 6 is that the increase in the price of natural uranium from present levels to the levels at which very large reserves of low-grade ores are available will increase the cost of the nuclear fuel cycle of converter reactors by at most 0.5 mill/kwh. Very likely, continuing improvement in efficiency and capital costs of nu-

* Proportional to the cost of U^{235} at 2% enrichment and normalized to $10.50/gm at $17.81/lb feed cost (*14, 23*).

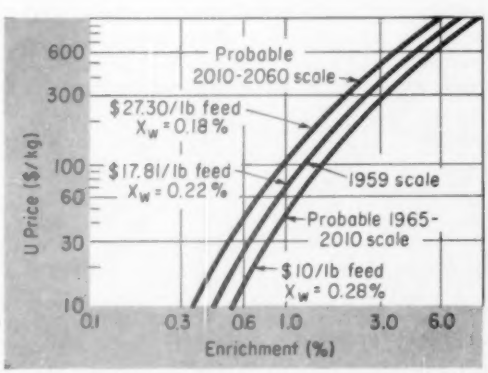


FIG. 5. ENRICHED-U PRICE CURVES for various costs of UF_6 feed. Separative work = $27.29/kg, and X_W is enrichment of waste stream from diffusion plant

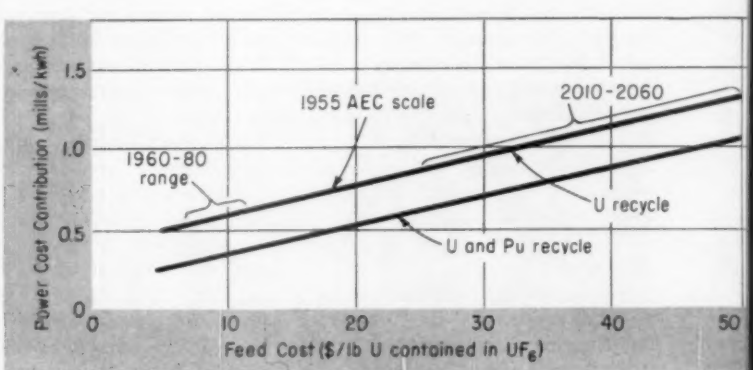


FIG. 6. POWER-COST TREND for converter-reactor economy over next hundred years showing effect of using lower-grade ores. Curves show a factor-of-6 range in ore price changes power cost by only ½ mill/kwh

clear-power generation will more than offset this small increase in fuel costs.

Inventory charges will also increase with increasing feed costs. With uranium recycle, inventory or use charges (at 4%) increase from 0.17 to 0.32 mill/kwh when feed costs go from $10 to $27. This increase of 0.15 mill/kwh becomes 0.3–0.4 mill/kwh if capital charges corresponding to private ownership of the fuel are used. Such an increase would tend to reduce the advantage of nuclear plants relative to fossil-fuel plants or "income-energy" sources. It is less important in comparing different reactor types since it depends only on average specific power.

Timing Breeders and Recycle

The justification of a breeder reactor depends upon its eventually becoming economic either because of improved performance or because of a combination of improved performance and the depletion of low-cost uranium resources by converter reactors. The depletion of low-cost resources by converters will probably require something like 50–100 years to offset a penalty of 0.5 mill/kwh in power costs for a breeder reactor, and over 100 years to offset a 1–2-mill/kwh difference.

This suggests that the role of the breeder for the next 50 years will be controlled mainly by the extent to which its performance can be improved —as measured by power costs in economic circumstances similar to the present ones—rather than by its ability to reduce the demand on raw materials.

On the other hand, recycle can reduce depletion costs by about 0.3 mill/kwh. Recycle, accordingly, mainly awaits the attainment of sufficient volume of fuel production to reduce the extra fabrication costs for plutonium-bearing fuels to below 0.3 mill/kwh (which is 50% of the fabrication costs expected by 1970). Accordingly, the general use of recycle for converter reactors seems reasonably assured within 20–40 years, unless fast reactors—in which plutonium value can have a 20–50% higher value—become economic rapidly enough to utilize the plutonium.

The long-term development of reactors that can extract energy from the enormous resources represented by the stockpile of depleted fuel from a converter-reactor economy (and also from thorium) seems an obvious necessity since this stockpile represents the major technically assured source of energy for future centuries. For most of the next century, however, semiquantitative upper limits to the incentives for breeder cycles are evident as follows:

- The potential economic advantage of a breeding fuel cycle is 0.5–1 mill/kwh over typical converter cycles.
- At present, this potential advantage is offset by the more stringent design and operating requirements of breeders which imply added burdens in capital and operating costs. The added burdens appear to be greater than the potential fuel-cost advantage (*26*).
- If the net cost penalty for a breeder were now only 0.5 mill/kwh, it would take 50–100 years of uranium use, as projected in Figs. 2 and 3, before the rising cost of uranium alone would bring breeder reactors to cost parity with present converter types.

Nevertheless, there are the following serious reasons for continuing to explore breeder-reactor technology:

- Although distant in time, there may be a valid long-term economic need for breeders.
- The presently apparent capital- and operating-cost penalties are probably not inherent in breeder-reactor systems. Attractive capital and operating costs may, in time, be attained with the reactor technologies that are capable of breeding.
- In common with other low-fuel-cost, high-capital-cost systems (like natural-uranium reactors), breeders may find use in power systems with low capital charge. (Provided other necessary conditions—such as a large well-integrated power grid—are also present.)

Because of the high costs and probable long duration of conventional breeder development (*26*), the effect of a parallel route to the same result, from the standpoint of resources, must be considered. In successive generations of converter reactors we can expect gradual increases in conversion ratios. The present incentive for this increase is not to conserve fuel material but to attain longer reactivity lifetimes. Longer fuel life reduces fabrication and reprocessing costs per unit of heat produced by the fuel. Improved conversion ratios are possible—as the incentives develop—even in reactor technologies not ordinarily regarded as potential breeders. For example, conversion ratios near unity, or even small positive net breeding gains, are possible even with light- water- and steam-cooled reactors (*24*).

As shown in Fig. 3, the annual additions to inventory for new capacity are only 7% of the total annual demand 50 years from now and 5% 100 years from now. Rising conversion ratios can eliminate most of the throughput component. For example, conversion ratios near unity have the effect of increasing the annual energy production for a given uranium demand by a factor of about 10 (allowing for moderate losses in recycle and a growing economy). Such a pattern of development seems more probable than the "pure" converter-reactor economy used to calculate uranium demand in Fig. 3. It has the effect of further delaying the time required for breeders to reach cost parity with nonbreeders to far beyond a century from now. This re-emphasizes the need to explore breeder-reactor technology in the next few decades primarily to find ways to reduce capital and operating costs, rather than to rely mainly on their ability to conserve fuel materials.

TABLE 3—U. S. High-Grade Reserves*

Year	*Estimated ore reserves (10^6 tons)*
1948	1
1952	3
1953	5
1954	10
1955	30
1956	60
1957	76
1958	82
(1959)	89

* From ref. *20*, for ore averaging about 0.28% U_3O_8. 1959 figure for first half of year.

Other Factors

The factors listed below have not been taken into account quantitatively because there is less evidence on which to estimate their future patterns than in the case of the factors considered earlier:

- Thorium supply and utilization
- Military, space-flight and process-heat demand
- Imports
- Demand in other countries

(*Continued on page 87*)

Radiation-Resistant Fluids and Lubricants

Several solid-film lubricants, greases and fluids show promising radiation resistance and high-temperature stability. Of particular interest as base fluids are polyphenyl ethers, which can stand 800°–900° F and 10^{11} ergs/gm C

By WILLIAM L. R. RICE,* DAVID A. KIRK
Materials Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio

and WILLIAM B. CHENEY, Jr.
U. S. Air Force Institute of Technology

RADIATION-RESISTANT LUBRICANTS are of major importance to portable nuclear systems, particularly extraterrestrial systems where shielding weight must be kept to a minimum and radiation doses are correspondingly high. Since organic fluids and lubricants are especially susceptible to radiation damage when under thermal stress, both thermal and radiation environments must be considered.

Development efforts have produced materials of outstanding capability. Solid-film lubricants and greases have been obtained which remain functional at high radiation doses and high temperature levels.

Base fluids, particularly the meta-linked polyphenyl ethers, have been developed which are promising for numerous applications, such as lubrication and heat transfer. These base fluids show capabilities of use at temperatures as high as 800°–900° F and radiation exposures as high as 10^{11} ergs/gm carbon.

System-development efforts now under way are expected to produce operating capability far in excess of that now available with conventional fluids and lubricants.

Work Under Way

Greases have been studied by a number of organizations (*1–5*), as have solid-film lubricants (*6*, *7*). General fluid development efforts have been outlined in several excellent reports (*8–11*) and a comprehensive survey made of fluids for use in nuclear reactors (*12*). Work on fluids for use in extreme-temperature systems is in progress (*13*, *14*), and evaluation of fluids and lubricants under dynamic conditions in the presence of gamma radiation has been undertaken (*3*). Fundamental study of the effects of high-intensity radiation on changes in chemical composition is also being conducted (*15*, *16*).

We shall summarize some results of the program of our Materials Laboratory and indicate the state of the art of high-temperature, radiation-resistant fluids and lubricants.

Solid-Film Lubricants

Solid-film lubricants generally consist of a finely divided solid, such as graphite or molybdenum disulfide, affixed to the bearing surface by a resin bonding agent. Other types, often used in conjunction with liquid lubricants, incorporate the lubricating material in a sintered metal matrix or employ high-carbon-content alloy bearing

* PRESENT ADDRESS: Fuels and Materials Development Branch, Division of Reactor Development, U. S. Atomic Energy Commission, Washington, D. C.

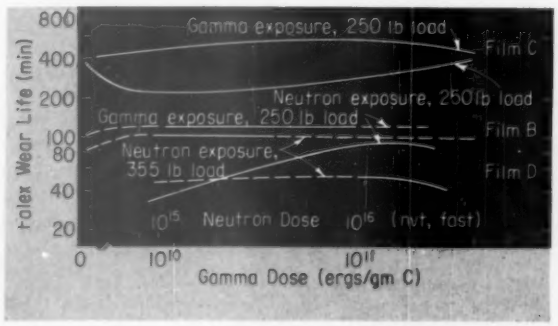


FIG. 1. EFFECT ON WEAR LIFE of solid lubricants of neutron and gamma radiation

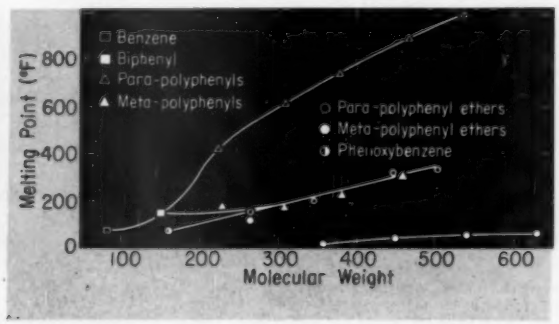


FIG. 2. MELTING POINT as function of molecular weight for potential lubricant base fluids

surfaces to support some degree of self-lubrication. Solid-film lubricants are designed to require no maintenance and last the lifetime of the bearing surface.

Figure 1 shows the improved wear life exhibited by a number of solid-film lubricants over a wide range of exposures (*7*). Note, however, that this effect appears to vary from film to film and that gamma radiation alone can play a vastly different role from that of mixed reactor radiation. Film C was markedly improved by reactor exposure but suffered considerable loss in wear life after gamma exposure. Solid-state characteristics, which are more critical under neutron bombardment, undoubtedly play an important role in the change in wear life.

As in all fluid and lubricant evaluation, dynamic evaluation is very important. Table 1 gives some preliminary data on in-source solid-film evaluation. Present data are insufficient to allow conclusions as to in-source wear life.

Wear-life tests conducted at −65° F indicate that solid films should have unlimited low-temperature applicability (*6*). Present resin-bonded films are usable up to ~500° F, with a probable radiation tolerance of 10^{11}–10^{12} ergs/gm carbon. For higher temperatures and dosages, the metal-matrix type now under development is probably the most likely candidate. Estimates of use life indicate possible temperature tolerance up to 1,000° F.

Greases

The primary drawback until recently in the development of a good high-temperature grease has been the base fluid. Thickeners have been available for several years which possess thermal stability in excess of any usable base fluid. The high-temperature greases formulated to date generally use silicone fluids. Although they possess wide liquid range, low volatility and high temperature stability, the silicone fluids generally have poor radiation stability and marginal lubricity. This has prompted research to develop greases of greater radiation stability (*2*).

Of the radiation-resistant greases developed to date, the terephthalamate-thickened alkyl diphenyl ethers are the most promising (*1, 2*). Such greases are usable from −30° to 350° F and at radiation dosages exceeding 7×10^{10} ergs/gm carbon, based on tests following static irradiation.

Dynamic evaluation of greases in the presence of gamma radiation is now under way. Table 2 gives this information for four commercial greases. The data are incomplete, but it is evident that operation at temperatures as high as 600° F is possible, even in the presence of gamma radiation; e.g., as shown for MLG 9305, operation for several hundred hours at 450° F is possible.

The outlook for the future is very promising. With the availability of the high-temperature polyphenyl ethers (see the following section), base fluids are now available which show outstanding thermal and radiation stability. Greases should be available in the very near future which will allow extended operation at temperatures as high as 800° F and down to 0°–50° F.

Fluid Development

The success or failure of greases, hydraulic fluids, engine oils and lubricants

TABLE 1—Dynamic Evaluation of Solid-Film Lubricants in Gamma Field*

Lubricant	*Wear life (hr)*	*Steady-state temp. (°F)*	*Wear scar area (in²)*	*Radiation to failure (ergs/gm C)*
Alpha-Molykote 106	33.9	140	0.0192	0
	7.5	150	0.0233	0
	48.2†	156	0.0188	0
	17.8	157	0.0231	0
	20.2†	147	0.0200	5.87×10^8
Everlube 620	20.7	146	0.0230	0
	14.7	160	0.0273	0
	60.6	155	0.0204	0
	85.5	158	0.0267	0
	34.7	144	0.0209	8.85×10^8
Electrofilm 4396	87.7	138	0.0229	0
	77.2	150	0.0167	0
	151.9	139	0.0164	0
	60.6†	129	0.0158	1.58×10^9
Surf-Kote 1284	129.7	145	0.0172	0
	114.7	140	0.0202	0
	79.8	144	0.0263	0
	73.3	141		2.01×10^9
	91.8	146		2.53×10^9

* Test conditions: Hartmann Modified MacMillan Test, 72 rpm, 630-lb load, according to C. R. C., 2/4/58. Data from reference *5*.

† These tests interrupted for ~5 hr owing to power failure. The load was removed before restarting and gradually replaced.

TABLE 2—High-Temperature Performance of Greases in the Presence of Gamma Radiation*

Grease†	*Dose (ergs/gm C)*	*Hours to failure*	*Condition of bearing*	*Condition of grease*
MLG 58-374	0	20.1	Noisy, jammed	Powdery
	0	33.5	Noisy, jammed, broken separator	Powdery
	0	11.9	Noisy, jammed, broken separator	Dry, hard
	4.59×10^8	16.9	Jammed, broken separator	Dry
MLG 9305	0‡	320.0	Noisy	Tacky
	0‡	595.7	Noisy	Gummy
	1.44×10^{10}‡	320.0	Jammed	Tacky
	1.30×10^{10}‡	280	(Test not yet complete)	
MLG 58-363	0	152.5	Jammed	Sludge
	0	7.3	Jammed	Gummy
	0‡	240.0	Jammed	Gummy
	1.25×10^{10}‡	234.9	Noisy	Tacky
MLG 58-355	0	60.0	Noisy	Gummy
	0	52.0	Jammed	Gummy
	8.80×10^9	200.8	Severe vibration	Gummy

* Tested as in Federal Test Method Standard No. 791-333T, 10,000 rpm. Data from reference (*5*).

† MLG 58-374—soap-thickened mineral oil composition; MLG 9305—arylurea-thickened silicone oil grease; MLG 58-363—copper-phthalocyanine-thickened silicone oil grease; MLG 58-355—dye-thickened silicone oil grease.

‡ Test temperature was 450° F; others tested at 600° F.

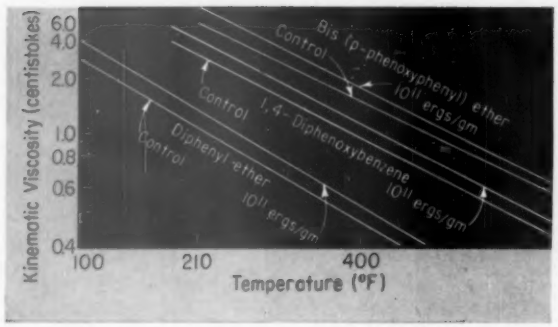


FIG. 3. VISCOSITY of irradiated polyphenyl ethers

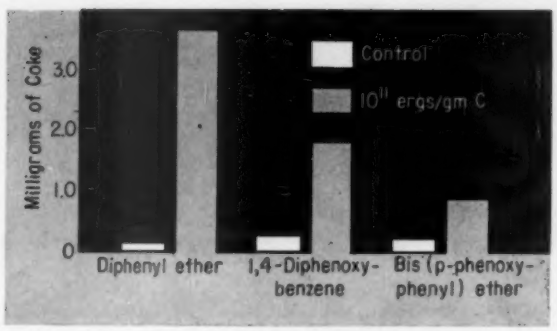


FIG. 4. COKE FORMATION of irradiated ethers

depends primarily on the capabilities of the base fluid. In the various applications, fluid shortcomings have previously been overcome with additives—for example, for hydraulic fluids, one uses viscosity-index improvers with small amounts of oxidation inhibitors, metal deactivators or antifoamant.

Under high-intensity radiation, base-fluid additives rapidly lose effectiveness (*19*). As a result, research efforts have been devoted toward tailoring a molecule with the necessary stability to oxygen, temperature and radiation without incorporation of additives. The result of this work (*8, 9, 11, 17, 18*) has been the establishment of a sound foundation of information on the polyphenyl-ether fluids. Tables 3 and 4 give the physical properties of some of the unsubstituted polyphenyl ethers.

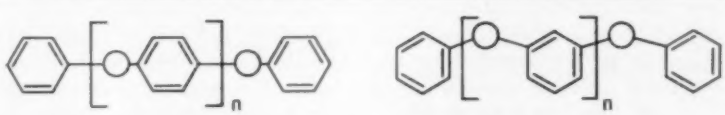
The all-meta isomers of the polyphenyl ethers comprise a series of great versatility. The data of Table 4 show that isomers are available to satisfy requirements for low melting point, low volatility, a range of viscosities and high-temperature operation.

As an example of the over-all promise of the polyphenyl ethers, one can compare the compound *m*-bis(*m*-phenoxyphenoxy) benzene (Table 4) with an MIL-L-7808 jet-engine oil in current use by the Air Force. The ether has a useful temperature range almost 200° F greater than the jet oil with an upper temperature limit almost 300° F higher. It has only 4% the volatility of the engine oil and forms only 1% as much coke at 800° F. Oxidation stability of the ether is over 1,000 times greater than that of the engine oil, a significant advantage in extreme-temperature jet-engine operation. The ethers are stable to radiation exposures from five to ten times greater than those which the MIL-L-7808 type of engine oil can tolerate. (*Continued*)

TABLE 3—Properties of All-Para Polyphenyl Ethers

*M.P.** (°F)	*B.P.** (°F)	*I.D.** (°F)	*Kinematic viscosity (cs)* 100° F	210° F	400° F	700° F	*Ref.*
Phenoxybenzene (*n* = 0)							
82.4	498		2.57	1.02	(0.45)		*8*
p-Bisphenoxybenzene (*n* = 1)							
167	724	>770		2.77	0.86	0.343	*8*
Bis(p-phenoxyphenyl) ether (*n* = 2)							
230	863	835		2.86†	1.51	0.53	*11*
p-Bis(p-phenoxyphenoxy) benzene (*n* = 3)							
300	999	825			2.60	0.78	*9*
Bis[p-(p-phenoxyphenoxy) phenyl] ether (*n* = 4)							
343	830	773‡			4.20		*11*
Di-2-ethylhexyl sebacate							
−45	640	575	12.58	3.30	1.07		*11*

* M.P. = melting point; B.P. = boiling point; I.D. = initial decomposition.
† At 300° F.
‡ Sample probably contained impurities.



Para Polyphenyl Ethers — Meta Polyphenyl Ethers

n = number of phenoxy groups in isomer

TABLE 4—Properties of All-Meta Polyphenyl Ethers

*M.P.** (°F)	*B.P.** (°F)	*I.D.** (°F)	*Kinematic viscosity (cs)* 100° F	210° F	400° F	700° F	*Ref.*
m-Bisphenoxybenzene (*n* = 1)							
118	702	>765	12.2	2.63	0.82	0.34	*8*
Bis(m-phenoxyphenyl) ether (*n* = 2)							
5p	900†	835	61.1	5.98	1.34	0.47	*11*
m-Bis(m-phenoxyphenoxy) benzene (*n* = 3)							
40p	999‡	870	332	12.7	2.04	0.63	*11*
Bis[m-(m-phenoxyphenoxy) phenyl] ether (*n* = 4)							
57p	1,125	842	3,000	24.9	2.94		‡
m-Bis[m-(m-phenoxyphenoxy) phenoxy] benzene (*n* = 5)							
70p	1,240	842	11,950	46.2	4.04	0.99	‡

* M.P. = melting point; B.P. = boiling point; I.D. = initial decomposition.
† Measured above decomposition point.
‡ Private communication from W. C. Hammann, Monsanto Chem. Co., Dayton, Ohio.

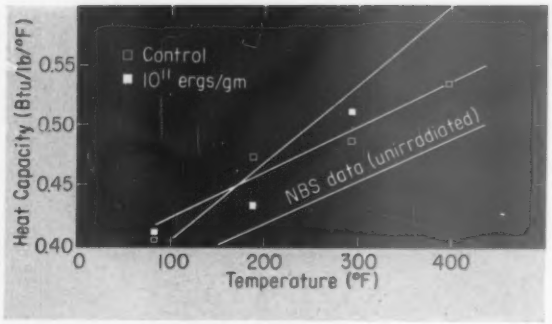


FIG. 5. THERMAL CONDUCTIVITY of polyphenyl ethers

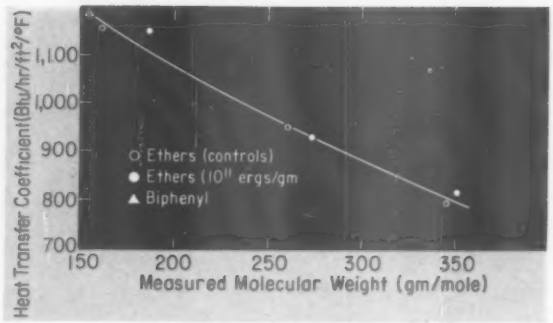


FIG. 6. HEAT CAPACITY of irradiated diphenyl ether

TABLE 5—Radiation Effects on Chemical Analysis

	Molecular weight (gm/mole)	*Elemental analysis*		
		% C	*% H*	*% O*
Diphenyl ether				
Theoretical	170.2	84.75	5.88	9.41
Control	164.0	84.73	5.90	9.39
1×10^{11} ergs/gm C*	183.3	84.70	5.95	9.38
1,4-Diphenoxybenzene				
Theoretical	262.3	82.40	5.34	12.20
Control	257.8	82.58	5.29	12.18
1×10^{11} ergs/gm C*	274.3	82.55	5.29	12.33
Bis(*p*-phenoxyphenyl) ether				
Theoretical	354.4	81.40	5.12	13.55
Control	344.5	81.23	5.03	13.48
1×10^{11} ergs/gm C*	350.7	81.25	5.03	13.51

* 3-Mev Van de Graaff generator.

The single class of compounds that appears to be competitive with the polyphenyl ethers is the chain-type polyphenyls, such as meta-terphenyl, etc. These compounds have oxidative, thermal and radiation stability equivalent to the polyphenyl ethers and are at present far cheaper to produce. The drawbacks, however, override the cost advantage and reduce their utility as wide-temperature-range lubricating fluids. The polyphenyls are extremely poor in lubricity and have much higher melting points, as shown in Fig. 2.

Irradiation results. The radiation stability of aryl ether compounds shows considerable promise (*19*). The thermal properties of certain of these ethers were investigated to determine their usability in a radiation environment.

Diphenyl ether, 1,4-diphenoxybenzene and bis(*p*-phenoxyphenyl) ether were tested. Three-kilogram samples of each were irradiated in the Shell Development Co.'s 3-Mev Van de Graaff generator under a nitrogen atmosphere to a total dose of 1×10^{11} ergs/gm carbon. Beam current was 1,000 μa with a 10-in. scan. The energy output was previously calibrated using an aluminum-block calorimeter. All irradiated samples were stored under nitrogen until tested.

Table 5 shows that molecular weight (ebulliscopic) increased somewhat with irradiation. The elemental analyses indicated little change. Melting and boiling points (Table 6) were lowered for the compounds. Vapor pressures increased and viscosity increased, as shown in Table 6 and Fig. 3. These changes indicate formation of higher-molecular-weight products as well as more volatile constituents as a result of irradiation.

Thermal stability, as indicated by the small-scale panel coke apparatus (Shell Development Co.), is shown in Fig. 4. Coke formation increased con-

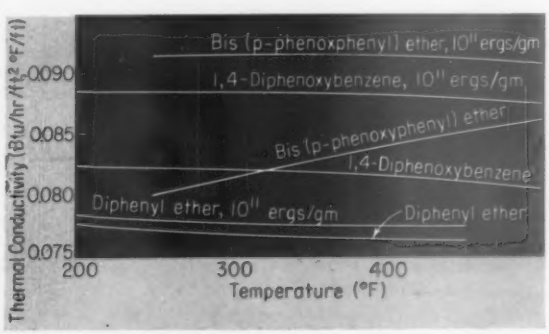


FIG. 7. HEAT CAPACITY of irradiated polyphenyl ethers. Lines are fitted by least squares method. Heat capacity of ethers is assumed to be linear function of temperature

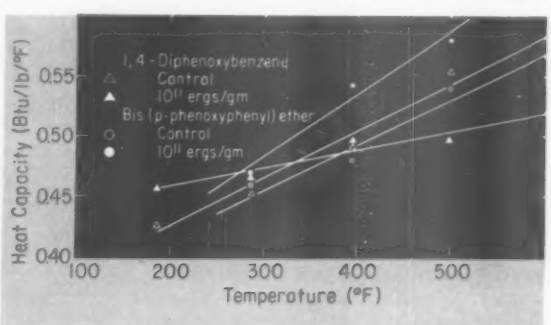


FIG. 8. CALCULATED HEAT-TRANSFER COEFFICIENT as function of molecular weight. Assumed conditions: long, straight tube, 0.1-ft diameter, 400° F, 20 ft/sec, unpressurized

siderably for all irradiated compounds, but was less severe for the higher-molecular-weight compounds.

Thermal conductivities are shown in Fig. 5. The values are taken from the composite line representing the heating and cooling curves determined experimentally (*20*). Heat-capacity data are shown in Figs. 6 and 7, the lines being fitted by least-squares determinations (*21*). It is assumed that heat capacity for the ethers studied is a linear function of temperature. This appears reasonable for the control samples at least, since diphenyl ether has already been shown to be linear over its liquid range (*22*). Heat capacities, as reported herein, may be somewhat optimistic compared with NBS data (see Fig. 6). This is because of an unresolved difference in experimental techniques. Since comparative changes are of interest here, this difference (about 10%) is not considered significant.

The data obtained permit an estimate of relative heat-transfer capability. The Dittus-Boelter correlation was used for assumed conditions similar to the example given by Glasstone for a number of coolants (*23*). The correlation should be fairly reliable, since experience has shown that it is acceptable for diphenyl ether. Figure 8 shows the results of the calculations. For convenience, the heat-transfer coefficients were plotted as a function of the measured molecular weight. For the conditions assumed, it would appear that irradiation to the dose specified had little effect on the over-all heat-transfer coefficient. While the diphenyl ether seems to be best for heat-transfer applications, the higher-molecular-weight ethers would be of interest where lower vapor pressure is necessary. The trade-off would depend on individual requirements.

Corresponding meta-linked aryl ethers have been irradiated to the same dose. When the data are complete, an attempt will be made to correlate the physical and thermal properties and the differences in structure.

* * *

The authors wish to express their particular appreciation to John A. King, Captain, USAF, who first recognized the great potential of the polyphenyl ethers, particularly the meta isomers, for use as extreme-temperature, radiation-resistant base fluids; through his guidance and direction, the development program was immeasurably enhanced. The authors also wish to express their appreciation to Mrs. N. E. Srp and Messrs. H. Marcus and R. A. Winn for their assistance in obtaining the data of Figs. 3–8 and Tables 5 and 6; the irradiations and coke determinations were conducted by the Shell Development Company.

TABLE 6—Radiation Effects on Physical Properties

	Diphenyl ether		*1,4-Diphenoxybenzene*		*Bis(p-phenoxyphenyl) ether*	
	Control	*1 × 10¹¹ ergs/gm C*	*Control*	*1 × 10¹¹ ergs/gm C*	*Control*	*1 × 10¹¹ ergs/gm C*
Melting point (°F)	81	73.5	166	131–160	230	217
Boiling point (°F, corrected)	508.3	503.6	732.2	687–716	865.4	695–700
Vapor pressure (mm Hg)						
200° F	7.5	27.5	3.9			
250° F				15.0		3.9
300° F	42.5	95.0	6.9	25.5	2.9	7.9
400° F	205.0	317.0	15.2	65.5	7.0	26.5
475° F		760.0				
500° F	765.0		54.0	170.0	15.6	71.0
600° F			210.0	510.0	41.5	180.0
650° F				835.0		
700° F			630.0		123.0	475.0
750° F						720.0
800° F					353.0	
865° F					660.0	
Kinematic viscosity (cs)						
100° F	2.71	3.83	Solid	Solid	Solid	Solid
210° F	1.02	1.31	3.02	4.17	6.27	10.27
400° F	0.50	0.57	0.88	1.06	1.49	1.80
700° F	Vapor	Vapor	0.42	0.47	0.57	0.62
Density (gm/cm³)						
100° F	1.0595	1.0772	Solid	Solid	Solid	Solid
210° F	1.0059	1.0265	1.0861	1.1169	Solid	Solid
400° F	0.9034	0.9266	0.9914	1.0176	1.0357	1.0549
Latent heat of vaporization (cal/gm)	73.3	136.6	73.8	1,024	98.9	1,633

BIBLIOGRAPHY

1. R. O. Bolt *et al.* Radiation resistant greases, California Research—AEC Report No. 8, AEC contract AT(11-1)-174 (1956)
2. R. O. Bolt, J. G. Carroll. Effects of radiation on aircraft lubricants and fuels, Wright Air Development Center Technical Report WADC 56-646, Part II (1958)
3. M. Z. Fainman *et al.* The behavior of fluids and lubricants in dynamic test equipment in the presence of gamma radiation, WADC 58-264 (1958)
4. J. R. A. Handschy *et al.* Greases stable to radiation under dynamic conditions, *Lubrication Eng.* **14**, 292 (1958)
5. W. L. R. Rice. The effects of nuclear radiation on military specification greases, WADC Technical Report 56-430, Part I (1956)
6. M. T. Lavik. High temperature solid dry film lubricants, WADC 57-455, Part II (1958)
7. W. L. R. Rice, W. L. Cox. The development of nuclear radiation resistant solid film lubricants, WADC 58-499 (1958)
8. E. S. Blake *et al.* High-temperature hydraulic fluids; Part III: Development of aromatic ethers as base stock, WADC 54-532, Part III (1957)
9. E. S. Blake *et al.* High-temperature base stock fluids, WADC 57-437 (1957)
10. E. E. Klaus, M. R. Fenske. Fluids, lubricants, fuels and related materials, WADC 55-30, Part VI (1958)
11. C. L. Mahoney *et al.* Development of prototype nuclear radiation resistant engine oil, Quarterly Progress Reports 1, 2 and 3 under contract AF 33(616)-5617 (Shell Development Company, Emeryville, Calif., 1958)
12. M. McEwen. Organic coolants for nuclear reactors, Technical Publication AT-1 (Monsanto Chemical Co., St. Louis, Mo., 1958)
13. R. H. Blackmer. Research on liquid metals as power transmission fluids, WADC 57-294 (1958)
14. Design and development of a 1,000° F hydraulic system, Progress Report 2, 10 July 1958 through 10 Sept. 1958 (Republic Aviation Corp., Farmingdale, New York, 1958)
15. E. M. Kinderman. Effects of high-energy, high-intensity electromagnetic radiation on organic liquids, WADC 57-465 (1957)
16. E. L. Zebroski, E. M. Kinderman. A comparison of high-energy electron and gamma irradiation effects on organic liquids, WADC 57-141 (1957)
17. C. L. Mahoney *et al.* Engine oil development, WADC 57-177 (1957)
18. C. L. Mahoney, *et. al.*, WADC 57-177, Part II (1958)
19. C. L. Mahoney *et al.* Polyphenyl ethers as high temperature nuclear radiation resistant lubricants, to be published in the *Journal of Chemical and Engineering Data*
20. D. W. McCready. Thermal conductivity of lubricating oils and hydraulic fluids, WADC 59-185 (1959)
21. T. M. Medved *et al.* Heat capacity determination of mineral and synthetic engine oils, lubricants, fuels, and hydraulic fluids in the temperature range 70° to 500° F, WADC 59-166 (1959)
22. D. C. Ginnings, G. T. Furukawa. Heat capacity standards for the range 14 to 1,200° K, *J. Am. Chem. Soc.* **75**, 522 (1953)
23. S. Glasstone, "Principles of Nuclear Reactor Engineering," p. 682 (D. Van Nostrand Co., Inc., New York, 1955)

How AEC Plans to Process

Processing of spent fuels of civilian reactors has been assigned to existing AEC facilities until industry can provide the service. Assignments were made to Oak Ridge, Hanford, Savannah River and Idaho on the basis of fuel type

By C. E. STEVENSON, *Phillips Petroleum Company, Atomic Energy Division, Idaho Falls, Idaho*

IN THE ABSENCE of private fuel-processing plants, the AEC has firmed up its own plans for processing spent fuels from research, test and power reactors until industry is ready to assume the task. This interim program, as recently described, will be based on adapting existing facilities at Oak Ridge, Hanford, Savannah River and Idaho. Each of these sites, according to its capabilities, has been assigned specific fuel types.

The costs of AEC processing services are based on a hypothetical ("conceptual") multipurpose plant,* i.e., one capable of treating a variety of dissimilar fuels. Costs charged reactor operators are based on this plant and are not necessarily related to actual experience. Present processing contracts with the AEC expire in June, 1967—or earlier if commercial services become available.

The decision to use existing facilities, with some modification, is based on two considerations: (1) the adequacy of available capacity to handle the projected fuel loads for some years and (2) the anticipated short duration of the AEC program, requiring minimum capital investment. On the other hand, distribution of the load among the four sites permits the maximum use of available technical talent to develop the required processes and minimizes the effect on over-all site programs.

Since AEC plants use solvent-extraction processes, these will form the basis of the interim program. The processes are of the Purex type, which makes use of tributyl phosphate (TBP) solvents, and the Redox type, in which the solvent is hexone. Thus, the fuel treatments used are not necessarily related to those of the conceptual plant nor to those that may eventually prove best for the various fuel types.

The complexity of the program is indicated by the fuel assignments listed in the table. Although only 18 reactors and reactor groups are specifically noted, the program currently includes, at least provisionally, fuels from 64 reactors or distinct reactor zones. A wide diversity of fuels is to be handled, but the trend in reactor development will probably be toward greater standardization—consequently this situation should not long prevail.

Considerable ingenuity has been applied in adapting the AEC-plant processes to the power fuels by developing suitable head-end feed-preparation methods. However, the reagents required to dissolve zirconium and stainless steel (e.g., hydrofluoric, sulfuric and nitric-hydrochloric acids) pose severe requirements for equipment construction materials; it is in this area that principal uncertainty as to process feasibility exists.

Another area to be studied is remote- versus direct-maintenance-type plants. The Hanford and Savannah River remote-type plants are equipped with elaborate cranes for removing defective "hot" equipment; the Idaho and Oak Ridge direct-maintenance facilities require thorough decontamination for changes and repair. However, any comparison is conditioned by the facts that the facilities were not designed specifically for the fuels to be processed and that the processing loads are small and of short duration.

Careful planning is needed for shipping fuel from reactor to processing sites, taking into consideration the handling facilities at the processing sites as well as safety in transit. AEC criteria covering shipment to all sites and additional criteria for the individual sites have been formulated.

The following descriptions give the major aspects of the processing capabilities at each of the sites.

OAK RIDGE

Fuels assigned. Stainless-clad low-enriched U-Mo alloy; 20%-enriched (foreign) U-Al alloy; highly enriched UO_2-ThO_2 in stainless and Al clad; Zircaloy-clad, U-Zr-Nb EBWR fuel; nominal capacity of ~300 kg U/day.

Mechanical equipment. Equipment will be provided for decladding, shearing and leaching studies, including removal of stainless from NaK-bonded alloys under oil and chopping of stainless- and possibly zirconium-clad oxides.

Dissolution and separation. Existing facilities providing nitric acid dissolution, 4 TBP extraction cycles, Pu partition and concentration and U^{233} isolation will be augmented by a new head-end chemical-treatment facility. Alternative flowsheets will be studied in a pilot-plant program. Stainless-clad UO_2 fuels will be declad with sulfuric acid and dissolved in nitric acid; alternatively fuel and cladding will be dissolved together in nitric-hydrochloric acid. Purex-type extraction will be used in either case. Stainless-clad ThO_2-UO_2 fuels will be declad in nitric-hydrochloric acid and the core dissolved in nitric acid

* Federal Register, March 12, 1957; NUCLEONICS 15, No. 5, 17 (1957).

Power Reactor Fuels

containing aluminum-complexed fluoride. A modified ammonium fluoride process will be used for EBWR fuel. Other fuels will be processed by conventional methods. Because of the diversity of available facilities, a major aim of the Oak Ridge program will be determining the most effective techniques.

Current Assignment of Fuel-Processing Responsibility

Idaho	Hanford	Oak Ridge	Savannah River
Shippingport core	Dresden	Enrico Fermi blanket	Enrico Fermi core
Organic Moderated Reactor Experiment	Yankee	Hallam (CPPD)	Chalk River reactors (NRX, NRU)
SM-1 (formerly APPR-1)	Shipping-port blanket	N. S. Savannah	
Vallecitos	Pathfinder	Indian Point	
Research and test reactors	Piqua	Elk River (RCPA)	
		Experimental Boiling Water Reactor	
		Foreign research reactors	

IDAHO

Fuels assigned. Highly enriched; bulk of load (several hundred kilograms of U^{235}/yr) will be aluminum-clad U-Al alloy from ~40 test reactors; principal power-reactor fuels will be PWR box-type Zircaloy assemblies, and OMRE, VBWR and APPR stainless box assemblies.

Handling, dissolution. A dry cave is equipped to cut and compress fuel and load storage buckets.

Aluminum fuels can be dissolved batchwise or continuously in mercury-catalyzed nitric acid, stainless-steel fuels in sulfuric acid, and Zircaloy fuels in hydrofluoric acid.

Fuel separation. The Idaho Chemical Reprocessing Plant has been recovering highly enriched uranium for about 6 yr. Only slight modifications are anticipated for fuels involved in this program. Redox and Purex processes will be used as appropriate.

Aluminum-alloy fuel solutions can be initially extracted with hexone or TBP; stainless and zirconium solutions are first treated with TBP. The concentrated uranium product stream is fed to a Redox-type process (hexone solvent).

Provision is made for collection, careful measurement and analysis of dissolver batches. An extensive statistical program has established the precision of these measurements.

HANFORD

Fuels assigned. Natural to 3.4% initial enrichment; Zircaloy, stainless or aluminum clad; all UO_2 except that from Piqua (U-Mo alloy); anticipated load of 36 tons in 1961 to 50–60 ton/yr after 1964.

Handling, decladding, dissolution. A mechanical-handling cell will provide for sawing, shearing and inspecting elements.

Chemical decladding is presently planned for all fuels—ammonium fluoride–ammonium nitrate for Zircaloy, sulfuric acid for stainless, and caustic soda or mercury-catalyzed nitric acid for aluminum. Core material is then dissolved in nitric acid; ferric nitrate may be added to retain molybdenum in solution.

Fuel separation. The Redox plant will be used for decontamination and plutonium recovery. Feed solution will be accumulated in batches large enough to permit using the plant for other functions. Use of the Redox facility gives the best balance of throughput capabilities to load and does not imply that the Redox process is more suitable than the recently installed Purex process.

New construction. A new building is required for receiving and handling fuel-shipping casks. Also needed are equipment for the fuel-storage, mechanical-treatment and dissolving facilities and a feed-solution pipeline to the Redox plant.

SAVANNAH RIVER

Fuels assigned. Rod- and plate-type Al-clad, natural-uranium fuel from the Chalk River NRX and NRU reactors; zirconium-clad, initially 25%-enriched U–10% Mo fuel from the Enrico Fermi Fast Breeder Reactor.

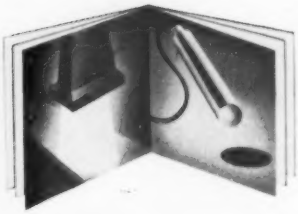
Decladding and dissolution. In the case of Chalk River fuel, aluminum cladding will be removed with caustic and uranium will be dissolved in nitric acid to prepare feed for the conventional Purex process.

The Fermi fuel consists of 32-in.-long, zirconium-clad U-Mo pins with stainless-steel wire spacers and locking bars, contained in a stainless housing. Subassemblies will be charged in groups of 4 to a stainless-steel dissolver. Zirconium cladding will be dissolved in very dilute, boiling hydrofluoric acid, and the U-Mo alloy will be dissolved in nitric acid containing aluminum nitrate to complex the fluoride. Undissolved stainless components will be withdrawn in the fuel-charging basket.

Separation. To maintain subcriticality while processing the enriched Fermi fuel, the extraction-process feed solution will contain no more than ~7.5 gm/l uranium; at this concentration, there should be no difficulty keeping the molybdenum in solution. U and Pu recovery will be by the conventional Purex process. Contacting equipment is of the mixer-settler type in contrast to the pulsed perforated plate and packed columns used at other sites.

* * *

This article is based on a meeting sponsored by the AEC Division of Production held at Richland, Wash., Oct. 20 and 21, 1959.



APPLIED RADIATION CASE HISTORY NO. 3

Irradiated Males

In 16 months a fly factory in a converted airplane hangar turned out three billion sterile flies to eliminate a costly menace to cattle herds of Southeastern ranches

By MERRILL E. JEFFERSON, *Department of Agriculture, Washington, D. C.*

THANKS TO RADIATION, cattle herds of Southeastern United States are no longer menaced by the screwworm fly. A fly factory capable of producing 100 million sterile flies a week overwhelmed the natural fly population with sterile males, raised and sterilized in captivity and then released from airplanes.

So successful was the method that the factory discontinued production last November 14—mission completed—several months ahead of the anticipated schedule. Appropriations of ~$10-million from the Federal Government and Southeastern States supported the effort to eliminate a pest costing Southeastern livestock producers an average of $20-million a year.

Life of the Fly

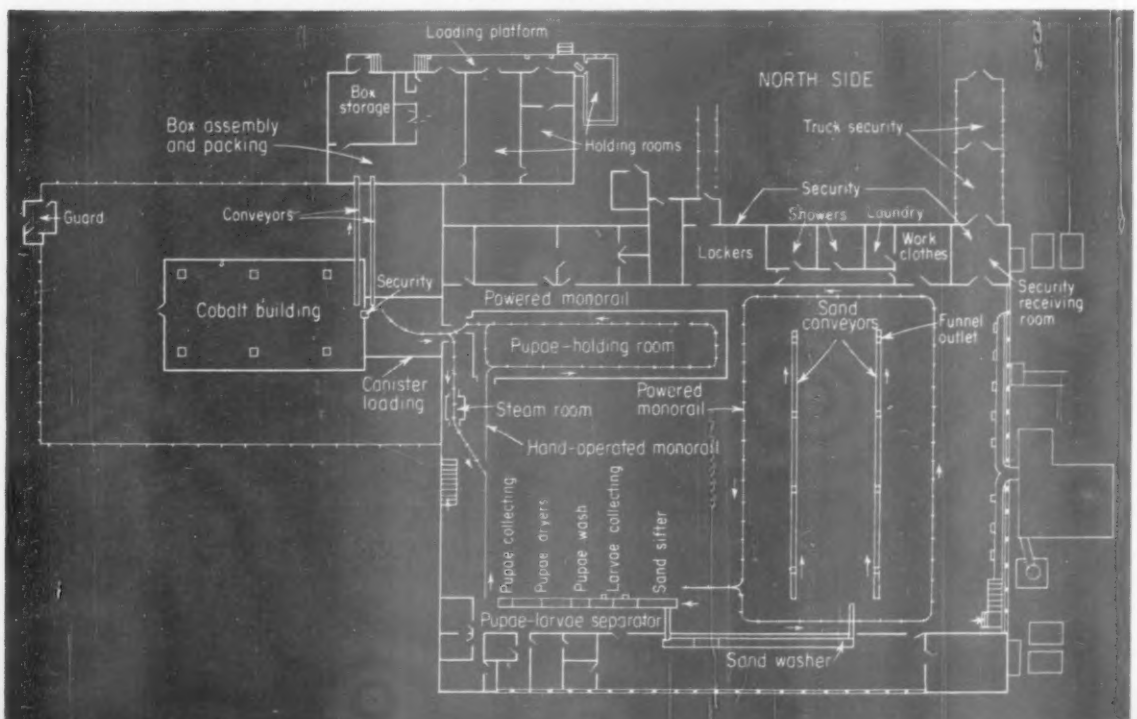
The red-eyed, blue-bodied screwworm fly (*Callitroga hominivorax*) can kill a full-grown steer in 10 days. The female lays its eggs in any open wound of a warm-blooded animal. The eggs hatch and tiny larvae (screwworms) burrow into the wound and gouge out a pocket in the flesh.

After they have lived for four or five days and done their damage to the host animal, the larvae drop to the ground and develop into flies. The total life cycle is only 21–28 days, and because the insects are subtropical, a cold winter kills off the pests. They remain a menace, however, when they are introduced into mild climates like those of the southern states, the West Indies, Mexico and South America. The flies migrate northward each season or spread by movement of infested animals. They can survive the winter in South America, Mexico, Florida and extreme southern parts of the Southwest.

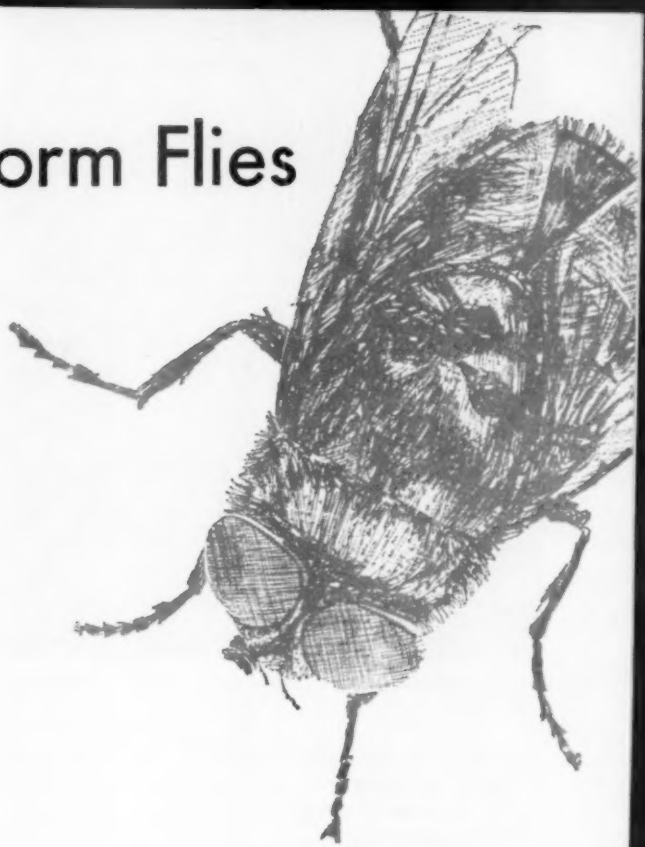
Eradication

Usual methods of insect elimination are not good enough for the screwworm problem. You can treat all domestic animals with ointments and sprays. These, however, are

FIG. 1. GROUND FLOOR OF FLY FACTORY is where pupae develop into sterile flies after hatching on floor above



Eliminate Screwworm Flies



Sterile-Male Method—Past and Future

Aside from its accomplishments in the Southeastern U. S., the sterile-male method of pest eradication has had successes elsewhere. It has been proposed for many problems and is being used for some of them.

The first great success was elimination of the screwworm fly on the island of Curaçao in 1954. A pilot test reduced screwworm incidence by 70% in a 2,000-square-mile area of Florida in 1957 before the full-scale attack was launched.

In cooperation with the government of Mexico, the U. S. Department of Agriculture has done some promising research work with this method against the Mexican fruit fly.

Belgium is working on a program to apply the sterile-male method to eradication of the tsetse fly in its African colonies, and a facility in Hawaii is directed at several fruit flies. The females mate more than once, but the mathematics of the method show that if sterile males make enough eggs sterile, the method may work with such insects (2). It has also been stated that such pests as small rodents might surrender to this kind of assult (2).

good for only a few days to a week at a time, and even if you clean up your herd completely, you can expect reinfestation from such animals as deer, raccoons and rabbits.

Eradication is accomplished by causing females to mate with sterile males (*2*). Afterward the female lays her sterile eggs, unaware that she has been frustrated in her natural purpose and apparently satisfied; she does not breed a second time.

The method depends for its success on rearing and sterilizing adequate numbers. In the Florida operation this has required an average of 50 million flies a week. A maximum of 70 million a week was reached, and full plant capacity was 100 million a week.

The fly factory is a converted World War II B-17 hangar at Sebring, Fla. It measures 160 × 200 ft and had operations on two floors. The ground floor is shown in Fig. 1. Three million fertile flies in a darkened adult colony produced larvae, which came to maturity on the upper floor and dropped through funnels into sand trays for pupation in the pupae-holding room. Pupation requires ~8 hr. After that pupae were held for 5.5 days at 80° F and 95% relative humidity to mature.

During the maturing period the trays remained at body temperature and moved slowly along as food was added and waste removed. Food requirements indicate the magnitude of the operation: 40 tons of ground meat, 9,600 gal of water, 4,500 gal of beef blood, 65 gal of plasma, and 35 gal of honey were required each week.

Sexual sterility was produced by exposing the pupae to 8,000 r of Co^{60} radiation two days before appearance of adult flies. Early research and tests showed that sterile males could be obtained with a dose of 5,000 r while 10,000 r had no adverse effect on development of the pupae (*3–5*); 8,000 r sterilizes the females among the released flies as well as the males to assure that there is no inadvertent contribution to the healthy population.

Elaborate precautions assured that none of the fertile flies escaped from the fly factory. These included changes of clothes and showers for all employees as they left work.

Distributing the Flies

Once reared and sterilized the fly battalions traveled to their theatres of operation in small Cessna 172 airplanes. Each plane carried 1,000 boxes of flies and flew for 5–6 hr each day over prearranged patterns in Florida and parts of Alabama and Georgia.

Pilots flew at 1,500 feet while insect dispersers loaded automatic ejectors. The ejectors dropped the boxes and opened them at a rate that dispersed 100–800 flies to each square mile of terrain. An air-conditioned station wagon carried flies to places that were hard to reach by plane.

To relieve anxieties of the human population, each box was marked to indicate the harmlessness of box and contents. Screwworm flies don't bite or look for picnic tables.

Irradiators

The radiation source used for early field tests was a cylindrical arrangement of Co^{60} slugs designed and built by Oak Ridge National Laboratory (*6*). This source was quite satisfactory and served as the basis for an irradiator of greater capacity and somewhat more uniform field.

Figure 2 shows one of the Co^{60} units at Sebring. The

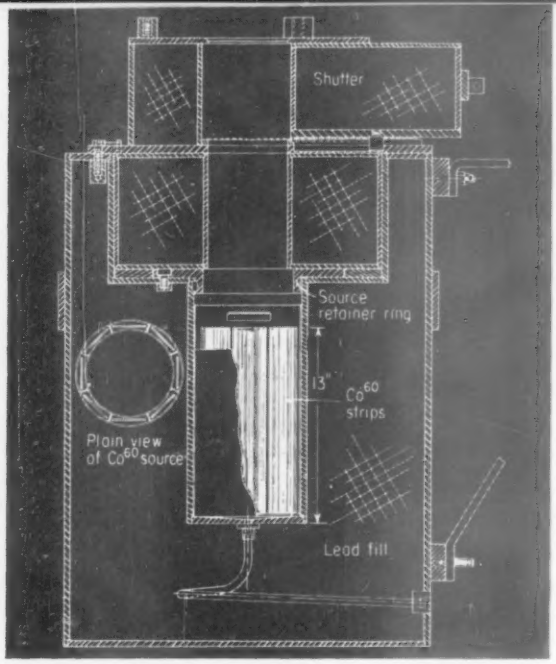


FIG. 2. IRRADIATOR has ~600 curies of Co^{60} in 8 flat plates

cobalt is in 2 × ½ × 13-in. stainless-steel-clad flat strips, produced by Brookhaven National Laboratory. Eight source strips are supported in a compartmented double-walled stainless-steel can with an effective radius of ~3.5 in. This array gives a cylindrical volume of 2.8 liters (~12.7 cm radius, 18.3 cm high) over which the dose-rate variation is ~10%.

There are six irradiators, four of which are shown in Fig. 3. The cobalt loading varies from 540 to 660 curies in each irradiator with a total of 3,600 for the six units (7). Average dose rate varies from 788 to 910 r/min. To take adequate account of biological variability, possible variation in the physiological pupal age, etc., exposure times were as long as 12–14 min.

Irradiation Procedure

Operation of an irradiator is essentially automatic. Pupae are measured by volume into canisters that hold ~18,000 each. The operator attaches the canisters to the elevator-conveyor. Then automatic controls take over, move the canister into position, open the cover, insert the material for irradiation during a preset time, remove the canister, close the port and return the canister to the load position.

Manual operation is also possible with electrical controls and in case of power failure hand operation bypasses all controls. Interlocks prevent driving the canister against the closed port or opening the port when the canister is not in position.

The shielding casks and handling mechanisms were fabricated by Knapp-Mills, Inc., Wilmington, Delaware.

FIG. 3. COBALT ROOM HAS 6 IRRADIATORS, each of which performs 13-min irradiation automatically once operator has inserted canister and started operation

Safety

Such devices have an obvious disadvantage: upon opening the port there emerges a cone of fairly intense radiation (several hundred milliroentgens per hour). This requires considerable vertical clearance and relatively light construction to minimize scatter. In the Sebring installation the eave line is ~14 ft higher than the top of the cask, and the roof is corrugated aluminum sheet on wood framing.

Personnel exposure has not been a serious problem since the general radiation level is ~2 mr/hr. For a fraction of a second during insertion and removal of pupae measured intensity of scattered radiation at the operator's position is 12–20 mr/hr. Film-badge and monitoring records indicate, however, that workers usually receive less than 50 mr per week. Special circumstances account for rare exposures as great as 75 mr.

Value and Cost

In 1957, its most successful year since it got into Florida in 1933, the screwworm was able to infest an estimated 80–85% of all cattle wounds in the state. Wounds are not hard to find—punctures, scratches, wire cuts, brands, fly bites and even navels of newborn animals.

Losses from such a rate of infestation were costing $10-million/year in Florida and $20-million/year in the Southeast. Shipment of infested animals and natural migration caused further loss in states as far north as New Jersey even though infestations in the north were checked by winter weather.

In comparison, Federal appropriations to support elimination of the fly have totaled $6.76-million. The Florida legislature appropriated $3-million for the two-year period ending in June, 1960. Substantial amounts were also expended by the states of Georgia, South Carolina, Alabama and Mississippi in support of the program. Approximately $425,000 went to remodel the plant; $584,000 went into equipment, including $106,000 for cobalt, shields, and handling and control mechanisms. Operating costs accounted for the rest. Extensive surveys and animal inspection are still being conducted to determine the effectiveness of accomplishments and protect the region from reinfestation.

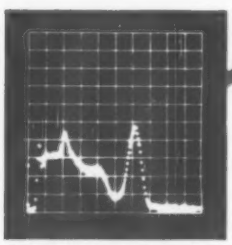
BIBLIOGRAPHY

1. Screwworm eradication program, Bulletins No. 1 and 2 (Florida Information Office, July and November, 1958); U. S. Dept. of Agriculture, Picture stories No. 108 (1958) and 116 (1959)
2. E. F. Knipling, *J. Econ. Entomol.* **48**, 459 (1955); *Sci. Monthly* **85**, 195 (1957); *Science* **130**, 902 (1959)
3. R. C. Bushland, D. E. Hopkins, *J. Econ. Entomol.* **44**, 726 (1951); *ibid.* **46**, 462 (1953)
4. A. H. Baumhover et al., *J. Econ. Entomol.* **48**, 462 (1955)
5. R. C. Bushland, Advances in pest control research (to be published)
6. E. B. Darden, Jr., E. Mayens, R. C. Bushland, NUCLEONICS **12**, No. 12, 60 (1954)
7. Survey of gamma facilities in U. S. and Canada—an updating, NUCLEONICS **17**, No. 7, 88 (1959)

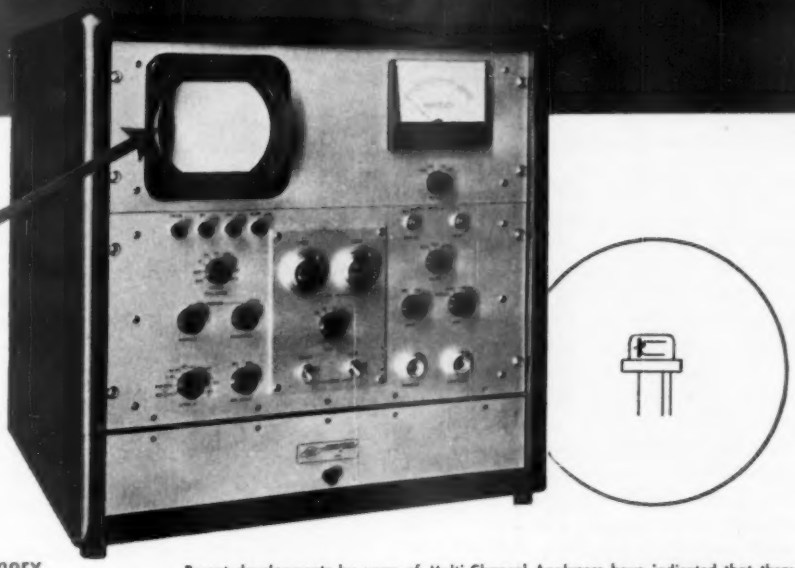
MAGNETIC TAPE READ-IN and READ-OUT WITH

MODEL 34-8

TRANSISTORIZED 200 CHANNEL ANALYZER



Cesium 137 spectrum photographed from CRT display of Model 34-8.



- Ferrite Core Memory
- 200 Channels
- Add-Subtract Logic
- Auto-Print
- Auto-Record
- Automatic Background Subtraction
- Memory Subgrouping
- External Programming
- Spectrum Transfer Circuit
- Coded Decimal Storage
- Parallel Coded Decimal Readout
- Multi-Channel Scaler Operation
- 10^5 Count Capacity
- Installation by Factory Engineer
- Course of Instruction Offered

Recent developments by users of Multi-Channel Analyzers have indicated that there is a need for an accessory device to transfer data from a conventional pulse height analyzer to an external storage element and reverse, i.e., put information stored externally into the pulse height analyzer.

The purpose of this accessory would be to provide the data storage and correction function with a minimum of external equipment. A system to accomplish these functions is now being developed by RIDL for use with the Model 34-8 Transistorized 200 Channel Analyzer. This system is intended to be used to substract arbitrary amounts of standard spectra from composite samples, to remove large peaks contributed by unknown amounts of known radiation and to reveal significant amounts of unknown radiation.

The majority of the necessary circuitry has already been incorporated into the basic Analyzer in order to minimize the overall cost of such a system. The principle external accessory to the Analyzer would then be a magnetic storage element such as an endless magnetic tape or a magnetic disc-type recorder. The pulse height analyzer is used to provide the standard samples for the magnetic tape and performs the arithmetic operations required for the subsequent subtraction of these samples from the unknown data.

The Model 34-8 is a completely new approach to the field of multi-channel analysis. This new approach, in conjunction with solid-state techniques—i.e., transistors in place of vacuum tubes, printed circuitry, etc.—allows compactness, low power consumption and heat dissipation and high reliability.

The STANDARD Model 34-8 is capable of operation as either a Multi-Channel Pulse Height Analyzer or a Multi-Channel Scaler (Time Analyzer). There are no extra plug-in modules to purchase in order to perform these separate functions. The change from one analysis mode to another is accomplished by the use of a single toggle switch.

The Model 34-8 is another of the NEW line of instruments designed and developed by RIDL. Whatever your instrumentation problem may be, RIDL has the solution. Our staff is always available to answer your inquiries. Write today to Dept. 58 for complete information.

Also Available
Model 34-12
Transistorized 400
Channel Analyzer

RIDL INC.

Radiation Instrument Development Laboratory, Inc.

5737 South Halsted Street, Chicago 21, Illinois • Phone TRiangle 3-2345

Representatives in major cities

Detection of Irradiation Effects by Differential Thermal Analysis

By C. B. MURPHY and J. A. HILL
General Engineering Laboratory, General Electric Co., Schenectady, New York

Differential thermal analysis (DTA), in which endothermic and exothermic peaks are recorded during slow heating of a material, has been found useful for indicating radiation damage of organic material and might be useful as a dosimetry technique.

The DTA technique uses the "bucked" thermocouple arrangement shown in Fig. 1. The substance undergoing transformation is placed in cell A. A reference material, undergoing no thermal transformations over the temperature range considered, is placed in cell B. The junctions of the opposed thermocouple circuit are imbedded centrally in these two materials. A third thermocouple, usually imbedded in the reference material (cell C), is used to measure the ambient temperature.

The thermoelectric output of the differential thermocouple circuit (cells A and B) is plotted versus time (or temperature in programmed heating systems). When a material is heated, if no transformations occur, both junctions of the differential thermocouple would exist at the same temperature. This would produce a straight-line trace on the differential recorder. If a phase change takes place in the material being examined, the material would absorb heat in the process. The thermocouple imbedded in the material being examined would lag that in the reference material, and the recorder would show a deflection or an arrest because of the generation of an emf in the circuit. Because a reaction rate is involved, and because of the gradual establishment of thermal equilibrium, a peak results on the thermogram. An exothermic reaction would establish a peak in the opposite direction to that described for the endotherm.

If radiation induces changes in material, some variation would be expected in the thermogram for the irradiated material from that of the nonirradiated material. The application of the DTA technique to detection of changes induced by radiation in biphenyl and several polymeric materials are reported here.

Experimental

Two types of sample holders and heating systems were employed in this investigation. The first, an infrared-heated graphite sample holder (*1*), was applied to irradiated and nonirradiated biphenyl. The second DTA system employed a sample holder and thermocouple circuit similar to that described by Stone (*2*) and electronic circuitry reported by Murphy, et al (*3*).

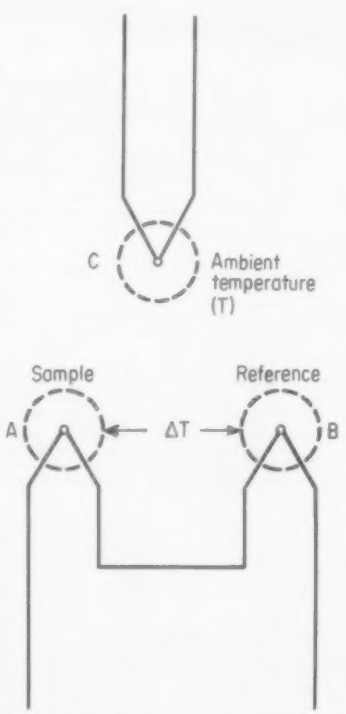


FIG. 1. DTA thermocouple arrangement; differential of thermocouples A and B is recorded as function of ambient temperature detected by thermocouple C; phase transformations of sample are recorded as endothermic and exothermic peaks

Eastman reagent-grade biphenyl was exposed to 700 megaroentgens of gamma radiation for 2,980 hr. Polyvinyl chloride and Teflon, in powdered form, and Versalube F-50, available as a liquid, were given a dose of 5×10^7 roentgens of gamma radiation from a cobalt-60 source at a rate of 3×10^5 roentgens/hr. Samples in each run were about 0.2 gm.

Biphenyl

Although conventional infrared analysis failed to detect a difference between irradiated and nonirradiated biphenyl, DTA detected such differences. The DTA results are given in Fig. 2.

Curve A of Fig. 2 shows endothermic reactions peaking at about 70° C and 175° C. The first peak is associated with the melting point and the second peak with the volatilization. Volatilization occurs over a broad range because of the thermal gradient inherent in the DTA system employed.

Thermogram B, Fig. 2, shows the same endothermic peaks as curve A and, in addition, an exothermic peak at ~370° C. The peak associated with the melting of the compound is slightly lower than that in curve A. The high-temperature exotherm is assumed to result from the air oxidation of the nonvolatile, radiation-induced biphenyl polymer remaining in the sample holder after volatilization of low-molecular-weight materials.

Because of the marked lowering of the melting point of irradiated biphenyl, verification of the melting-point depres-

big stuff to quality-inspect?

need to radiograph giant castings
for reactor systems?
or weldments on thick-walled
pressure vessels?
or feet-thick solid fuel volumes?
or even heavy lead slabs, maybe?

such jumbo jobs are meat for the massive power (2-3 million volt equivalent) of Picker's Cobalt 60 **Cyclops.** *for instance . . .*

it will find a flaw this small in a 10" thick steel casting . . . the penetrameter will show clearly on the film

(Cyclops users readily produce radiographs that meet and often better the 2% sensitivity requirements of most radiographic inspection codes.)

with radiographic power like that, Cyclops makes short shrift of less formidable jobs, too . . .

gets through 5" of steel in 5 minutes

(And thanks to its unique collimator, secondary radiation is so cut down that radiographs made with Cyclops are characteristically snappy with detail-disclosing contrast.)

Cyclops is compact enough to mount on a go-to-the-job mobile carriage

(Or on a variety of other supports tailored to the workload. Seen here is a jib-mounted unit at Cooper-Alloy Corporation

big surprise **is Cyclops low cost**

(about one-fourth the price of equivalent energy x-ray equipment)

Picker X-ray

There's much more to tell about Cyclops. Get the full story from your local Picker office (see 'phone book) or write Picker X-Ray Corporation, 25 So. Broadway, White Plains, New York.

This article starts on page 78

sion was determined by running irradiated biphenyl versus nonirradiated material as the standard. This thermogram, curve C, shows exothermic peaks at about 70° C, 200° C and 365° C and an endothermic peak at about 65° C.

Both low-temperature peaks are associated with melting of the materials. The initial endothermic effect indicates a lowering of the melting point of biphenyl caused by radiation-produced impurities. Subsequent to this, the nonirradiated material melts and produces the exothermic effect. Because two simultaneous reactions are occurring, only the net effects are observed, and the areas of both peaks are smaller than those observed with DTA of the individual materials versus alumina.

The exothermic peak at 200° C shows the same kind of variation in physical properties associated with volatilization of the two materials as was observed with liquifaction. The exothermic peak at 365° C, again, is associated with oxidation of nonvolatile, high-molecular-weight radiation products.

Polyvinyl Chloride

The two thermograms for polyvinyl chloride, Fig. 3, show the same general kind of phenomena. The nonirradiated sample exhibits the essential features of the thermogram obtained by Rice and Morita (*4*). At about 300° C, endothermic peaks are observed in both materials, and these are followed at higher temperatures by complex exothermic peaks. The high-temperature phenomena are complete at 635° C for the nonirradiated material, while, in the irradiated specimen, this effect is observed at about 650° C.

The endothermic peak at 300° C, known to result from the evolution of hydrogen chloride from the polymer (*5*), is decreased in the irradiated specimen. This indicates hydrogen chloride evolution on irradiation. In the nonirradiated polyvinyl chloride, the hydrogen chloride release is followed by a flattened exothermic peak. Such peaks are not generally found in differential thermal analysis, and, in this case, it is believed to be the net effect of two thermally competing reactions: (1) the continued endothermic loss of hydrogen chloride and (2) the thermally induced crosslinking of the unsaturated bonds resulting from hydrogen chloride release. The flattened peak occurs at a stabilized rate of reaction, most probably controlled by the rate of evolution of hydrogen chloride. In the irradiated polyvinyl chloride, there is only a slight exothermic trend observed to follow the endothermic reaction. Radiation-induced polymerization in the polymer would be expected to restrict the freedom of motion necessary for the formed ethylenic linkages. This would limit the extent of thermally induced polymerization of such bonds and result in a reduced exothermic peak.

High-temperature exotherms encountered in the irradiated and nonirradiated polyvinyl chloride would be expected to show variations resulting from the differences in structure as explained previously.

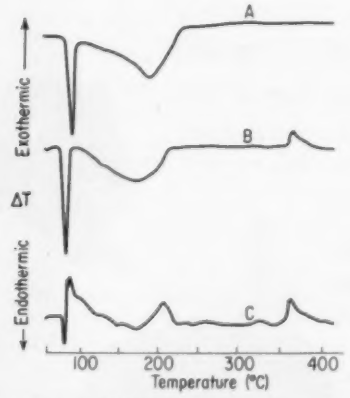


FIG. 2. DTA OF BIPHENYL. Curves are for (A) nonirradiated biphenyl, (B) irradiated biphenyl and (C) irradiated biphenyl versus nonirradiated biphenyl as reference

Teflon, Versalube F-50

Irradiated and nonirradiated Teflon show an endothermic peak at 340° C that is the result of a solid-phase transition. An increase in the endotherm indicates that irradiation increased the quantity of material responsible for the peak.

An exothermic peak at 570° C results from oxidative decomposition. Although irradiation caused no marked deviation, the onset of the reaction occurred at a lower temperature.

Irradiation converted Versalube F-50 from an oily fluid to a resinous mass, which was then treated as a solid. Irradiated and nonirradiated specimens exhibited an exothermic decomposition starting at ~360° C. This is associated with a high fraction of dimethyl siloxane, which undergoes a siloxane rearrangement at 310°–320° C. The flattened peak of the irradiated material shows decreased siloxane rearrangement because of the greater rigidity of the radiation-induced crosslinking.

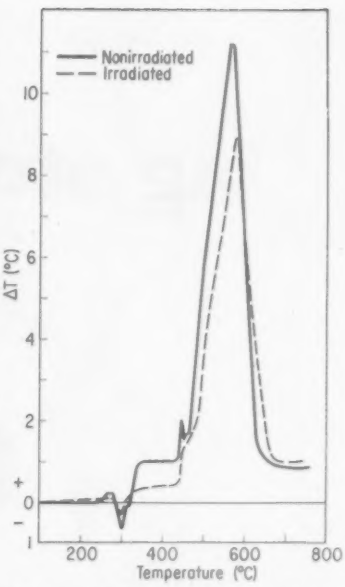


FIG. 3. DTA OF POLYVINYL CHLORIDE. Endotherm results from hydrogen chloride evolution and exotherm from crosslinking

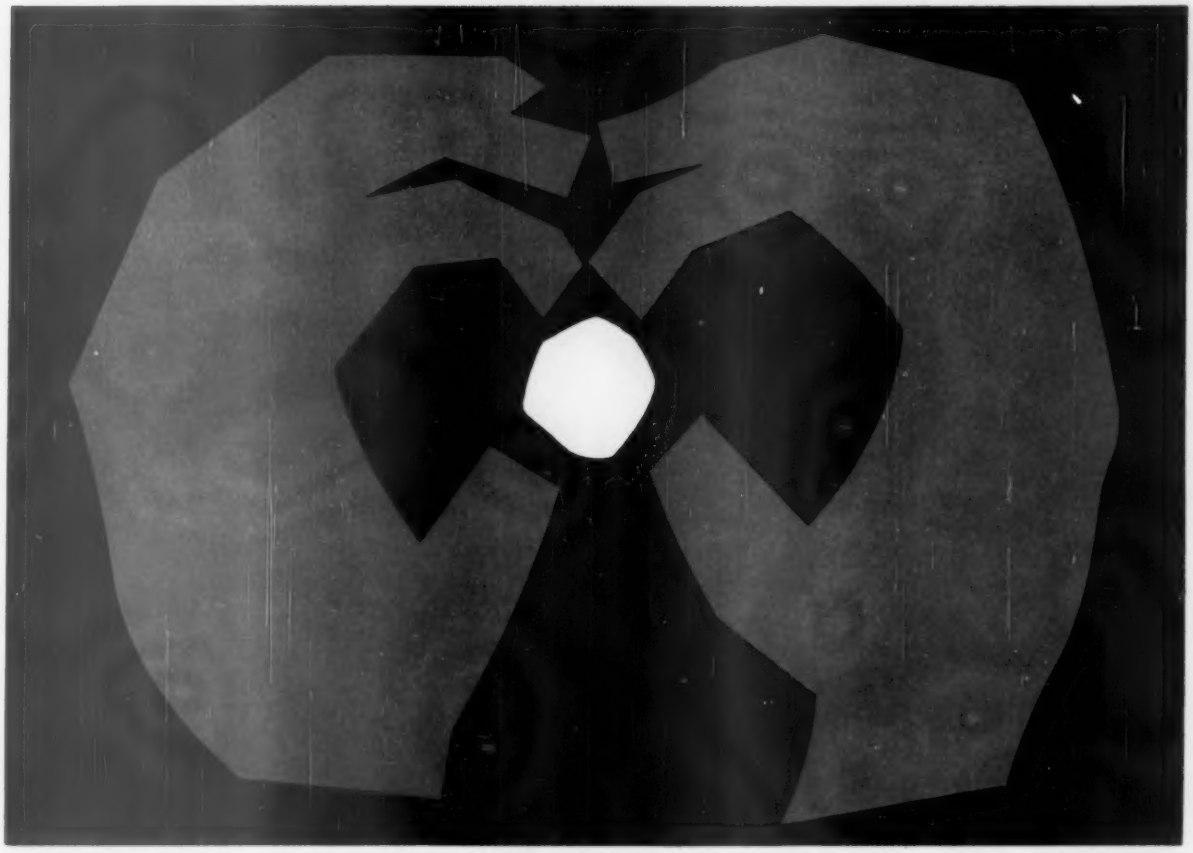
Applications

Biphenyl is reasonably resistant to radiation damage, a fact attested to by its proposed use as an organic reactor coolant. By applying this technique to other organic materials, either increased or decreased resistance to radiation damage will be observed.

The relationship of peak area to the heat of reaction and thus to a quantitative measure of material undergoing reaction has been shown by several investigators (*6*, *7*). Thus, by selecting materials on the basis of the relationship of peak area to radiation dose, the DTA technique might be applied to dosimetry over a wide range of energy levels.

BIBLIOGRAPHY

1. J. A. Hill, C. B. Murphy, *Anal. Chem.* **31**, 1443 (1959)
2. R. L. Stone, *J. Am. Ceram. Soc.* **35**, 76 (1952)
3. C. B. Murphy, J. A. Palm, C. D. Doyle, E. M. Curtiss, *J. Polymer Sci.* **28**, 447 (1958)
4. H. Morita, H. M. Rice, *Anal. Chem.* **27**, 336 (1955)
5. J. Hill, C. Murphy, unpublished results
6. L. T. Alexander, S. B. Hendricks, R. A. Nelson, *Soil Sci.* **48**, 273 (1939)
7. H. Borchardt, F. Daniels, *J. Am. Chem. Soc.* **79**, 41 (1957)



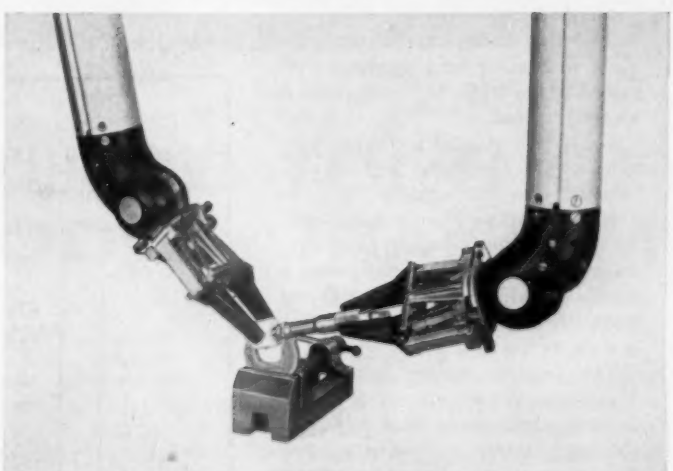
CRL manipulators...

AS OBEDIENT AS YOUR HAND!

Slave ends of CRL Manipulators obey perfectly—duplicate the natural motions of the operators' hands—make operation of the system amazingly simple. An operator becomes perfectly adept with practically no training.

Simplicity of operation is only one of several reasons research and production organizations all over the world specify CRL Manipulators. The system is versatile. Accessories such as special-purpose tongs, load hooks, motion locks, and protective booting allow adaption to a great variety of purposes. A continuous program of improvement . . . uncompromising workmanship . . . and standardized, interchangeable parts provide more reasons why you should consider CRL Manipulators for handling hazardous materials.

Central Research Laboratories will be glad to advise you on the handling of radioactive materials, explosives, hazardous chemicals, biological materials—in the layout of hot cells—in other research areas, too. For complete information, write CRL today.



Central Research Manipulators from basic Argonne National Laboratory design

Central Research
laboratories, inc.
Red Wing, Minnesota, Dept. 101

VOICE-AMPLIFIER SYSTEM comprises miniature microphone (Shure model mc-20J) in gas mask (Dustfoe Ultra Filter) connected by coaxial cable (Micro-dot type 50-3920 CW) to amplifier box worn on belt. Face-mask and amplifier-box receptacles are Amphenol 27-9, a miniature coax-type male; cable plug is Amphenol 27-7

Transistorized Voice Amplifier for Use with Respiratory Masks

By J. R. GASKILL and O. L. MEADORS
Lawrence Radiation Laboratory
University of California
Livermore, California

During emergencies encountered in handling radioisotopes or other toxic materials, personnel must often wear dust masks or contained-air-supply respirators. Communication between wearers of such apparatus is difficult because the face mask muffles the voice. Even with a speaking diaphragm installed in the mask, the voice range is severely limited.

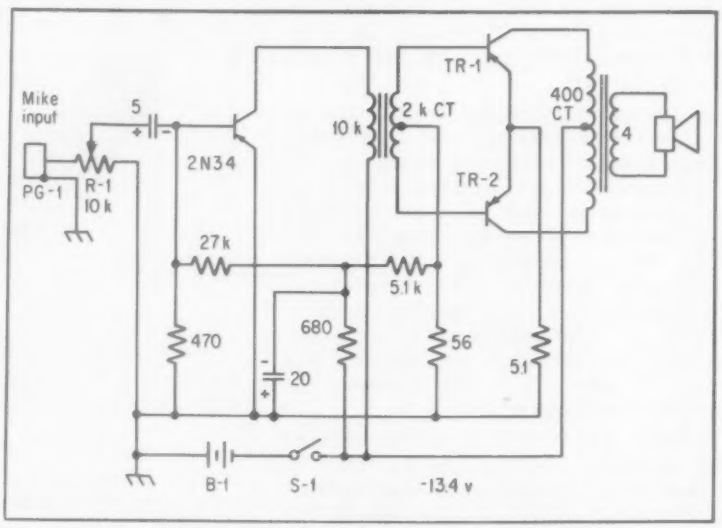
We have developed a transistorized voice-amplifier system for use with various types of respirators, such as Dustfoe, Scott or Mine Safety Appliances. A miniature microphone is installed inside the face mask, with a coaxial cable led out through an O-ring seal to the amplifier-speaker box, which is worn on the belt.

The amplifier-speaker box weighs 1½ lb and measures 4 × 4 × 1¾ in. It can be contained in a thin polyethylene bag to protect it from contamination without imparing the audible range, which is up to 400 ft when the unit is worn outside the clothing or 100 ft when worn inside a 20-mil plastic protective suit.

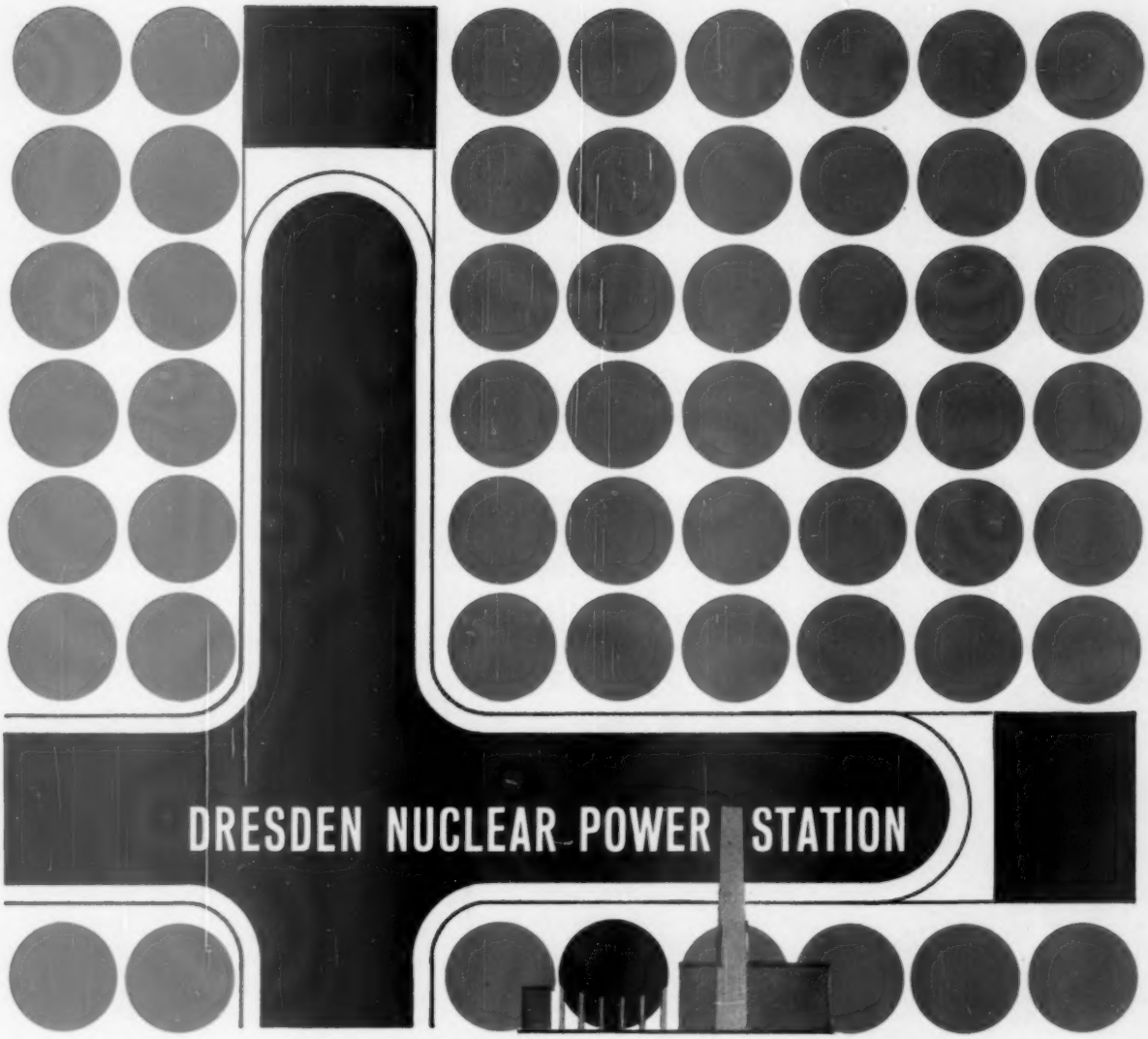
The battery life is about 20 hr with continuous usage. The shelf life is about 1 year. There have been few maintenance problems, and the units are very rugged. The cost is about $60 per unit.

* * *

This work was done under the auspices of the U. S. Atomic Energy Commission. The authors wish to acknowledge the work of the following in designing and fabricating the voice amplifier: William Abernathy, Paul Dane, R. P. Rufer, Paul Tull, N. C. Jenson and C. G. Henderson.



AUDIO AMPLIFIER uses printed-circuit board. S-1 and R-1 (on-off switch and volume control) are one unit. TR-1 and TR-2 are matched 2N224 transistors. Unit is powered by two Mallory TR-135R 6.5-volt batteries in series. Speaker is 3-in. RCA-23151



FUELED WITH 60 TONS OF MALLINCKRODT URANIUM

This reactor, as well as those of Yankee Atomic Power Company and Consolidated Edison Company, depends upon commercially produced nuclear fuels. The uranium loading of all three will be entirely or in part Mallinckrodt UO_2. ◆ As the roster of reactor projects grows . . . so does the number of Mallinckrodt nuclear customers. Whether power, propulsion or experimental—domestic or overseas—Mallinckrodt has unequaled experience in producing nuclear fuel materials. ◆ The core loading of Dresden, designed and fabricated by General Electric Co., will be 136,000 pounds of UO_2 (1.5% enrichment) . . . equal to approximately 1,800,000 tons of coal. This 180,000-kilowatt plant will be owned by Commonwealth Edison Company. ◆ Mallinckrodt produces more than fifteen different forms of uranium compounds and metal. Now, with the completion of an automated pellet plant, Mallinckrodt can deliver completed fuel elements by working with metal fabricators. ◆ For consultation on nuclear fuel problems write or call Mallinckrodt.

MALLINCKRODT NUCLEAR CORPORATION · ST. LOUIS 7, MO.

THE WORLD'S FIRST AND LEADING PRODUCER OF NUCLEAR FUELS

VICTOREEN

WORLD'S FIRST NUCLEAR COMPANY

TRANSISTORIZED SPECTROMETRY

A DUAL INPUT TRANSISTORIZED 200-CHANNEL SPECTROMETER

featuring

DIFFERENTIAL DATA ACCUMULATION

TULLAMORE-DESIGNED
MODEL ST-200D. For complete details write for Victoreen Form 3121-9.

The new VICTOREEN MODEL ST-200D Spectrometer will accept two inputs simultaneously and will add, subtract, or separate the data *during the accumulation process.*

Features

- 200-channel ferrite core memory
- Decimal address and storage—no decoding necessary in printout
- 10^5 counts/channel
- Automatic bi-directional decimal storage
- Parallel data readout
- Printout at 4 channels/second
- 5" CRT display
- Two independent amplifiers and preamplifiers
- Neon digital indicators
- Built-in precision pulse generator
- Memory subgrouping

Applications

- 4-pi scintillation spectrometry
- "Peel-off" analysis of complex spectra
- Simultaneous background subtraction
- Summation of independent spectra
- Decay scheme studies
- Health physics identification studies
- Whole body counting

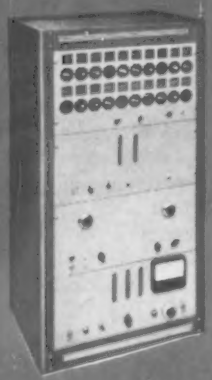
The Victoreen Instrument Company

5806 Hough Avenue • Cleveland 3, Ohio

Export Department, 240 West 17th St., New York 17, N. Y.

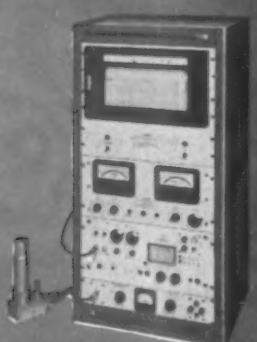
Cable: TRILRUSH, New York

TULLAMORE-DESIGNED
SPECTROMETERS
THE INDUSTRY STANDARD FOR
NUCLEAR INSTRUMENTATION



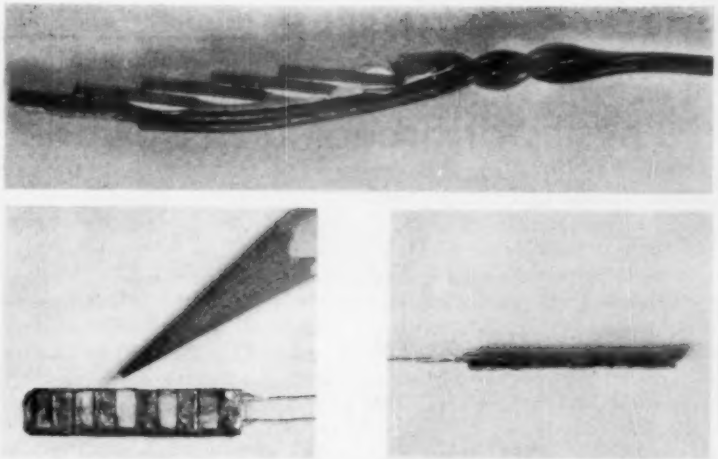
Model PHA-130. A multichannel analyzer at a single-channel price.

Model ASP-1ADR. Automatic channel-by-channel analysis of complete spectrum. Print (digital) and plot (analog) simultaneous readout.



Model SS-1. Single-channel scanning spectrometer with automatic electronic sweep.

The Victoreen Instrument Company
5806 Hough Avenue
Cleveland 3, Ohio



FISSION PROBE constructed by soldering uranium-235-coated silicon *pn*-junction wafers in series arrangement provides compact unit for flux mapping. At top is shingled arrangement and below the later, more compact version (top and side views)

Semiconductor Fission Probe

By ROBERT STEINBERG
Lewis Research Center
National Aeronautics and Space Administration
Cleveland, Ohio

Series connection of uranium-235-coated silicon *pn*-junction wafers (see above) provides a compact probe for flux-mapping in a low-power reactor.

The main drawback to semiconductor neutron detectors has been low counting efficiency (Babcock *et al.*, NU, April '59, p. 116). Since the fission-fragment range in uranium is short, optimum thickness is ~2 mg/cm² for U_3O_8, and since pulse height per incident fission fragment is inversely proportional to junction capacitance, increasing the area would reduce pulse size.

We propose a simple solution: series-connecting silicon wafers, as above, increases surface area without greatly reducing pulse height. Whereas counting efficiencies of 10^{-7}–10^{-6} count/n/cm² have been measured for single wafers, a detector made of ten wafers in series with a total area of 1.12 cm² had a sensitivity of 1.0×10^{-3} count/n/cm² and ~0.75-mv pulse height (~25% decrease from the single-wafer pulse height).

In the shingle construction shown in the photograph, five wafers were soldered in series and two of these units connected in series to make a probe small enough to fit between MTR-type fuel plates. Each five-cell unit measures $0.13 \times 0.33 \times 1.30$ cm; two units in series have a surface area of 0.645 cm² and a sensitivity of 1×10^{-3} counts/n/cm².

A later version provides an even more compact probe having the same sensitivity. Rather than overlapping the wafers as in the shingle construction, it was found feasible to solder them side by side, as shown in the photograph. However, to conveniently solder the wafers in series, the U^{235}-coated surfaces of the wafers are alternately faced in opposite directions. Each wafer is coated with 2 mg/cm² 90%-enriched U^{235}. The complete unit is potted to prevent flaking of the uranium and to insulate the probe when it is inserted in an aluminum housing. The complete detector, including potting, measures $2.2 \times 0.5 \times 0.17$ cm. The maximum fission pulse height is 0.75 mv.

An alternative method to soldering, offering more versatility in choice of cell size and geometry, is to use conducting cement to bond the cells together. This technique has been tried, and found satisfactory.

The series approach, while relatively simple, fulfills the present need for a small compact probe with a reasonable counting efficiency. It is felt that the useful limit of series circuitry will be an efficiency of 1×10^{-3} counts/n/cm².

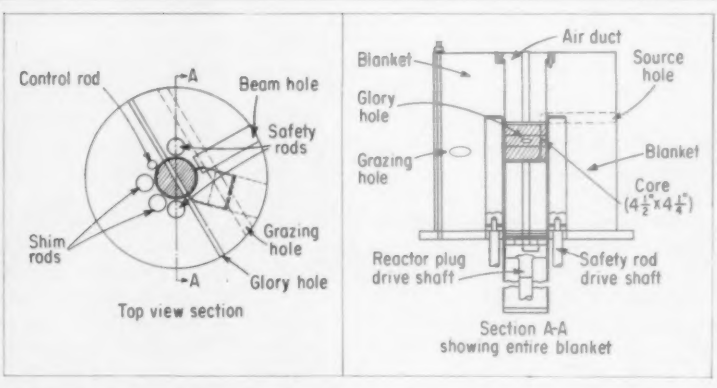
For another semiconductor detector, see cover and article on p. 54.

Physics of Breeding Reviewed

A conference of U. S. reactor physicists (at Argonne National Laboratory, October 19–21) agreed that the breeding potential of fast reactors has been firmly enough established to allow reactor physicists to concentrate on problems closer to engineering design; in addition, the conference heard accounts of recent work that encourage optimism for thermal breeders.

David Okrent (ANL), chairman of the meeting, observed that a practical fast-reactor design, with uranium-alloy fuel and the required amount of steel structural and sodium coolant, can achieve an initial breeding ratio of 1.6. He finds this figure is rather insensitive to reasonable variations in the amount of structure, to errors in input cross sections or to fission-product buildup. The real difficulty with such a design is in the metallurgical and reprocessing problems of the metallic fuel. Alternative fuels suggested at the meeting included PuC dispersed in U alloy or $U^{233}C$ in Th, UO_2-PuO_2 ceramic mixtures, and liquid-metal elements encased in Ta. The PuC fuel entails a breeding-ratio loss of 0.1–0.2 and the U^{233}-Th carbide system an additional loss of 0.3.

Eta of U^{233}. Ever since the 1958 Geneva Conference, thermal-breeder concepts have been dogged by the suspicion that η for U^{233} might be considerably less than 2.28. New measurements in both the U. S. and U. K. and reanalysis of the old U. K. measurements (which originally raised the issue) now definitely rule out this possibility. Oak Ridge now places η for U^{233} between 2.28 and 2.30.



Source Reactor for Argonne Fast-Reactor Studies

The Argonne Fast Source Reactor (AFSR), which went critical in October at NRTS, will provide a laboratory source of neutrons for development work on special experimental equipment for the fast-reactor program centered around Experimental Breeder Reactors I and II and the Zero Power Reactor III.

The priority job for the economy-priced (~ $125,000) AFSR will be to help develop methods of measuring neutron spectra in the difficult region below fission energies and above 30 kev.

The reactor core is solid, highly enriched uranium contained in three thin nickel cans which, when assembled, form a cylinder 4.5 in. in diameter by 4.5 in. high. The core is surrounded by a reflector of solid depleted uranium 8 in. thick. Cooling air is drawn through a 1/16-in. annulus between core and reflector. The design power level is 1 kw; the corresponding central core flux is 6×10^{11} neutrons/cm²/sec. Thermal fluxes of the order of 10^8 are available in the graphite thermal column.

Control is obtained (1) by lowering the lower core can and the plug of blanket material beneath it and (2) through the motion of five rods of blanket material in the blanket.

Argonne plans to use AFSR to develop neutron spectrometers, to improve methods and equipment for statistical studies of neutron populations (e.g., Rossi-α method) and to irradiate foils for radiochemical studies. For further details see G. S. Brunson, et al., Design and Hazards Report for the Argonne Fast Source Reactor (AFSR), ANL-6024.

Be(n,2n). Breeder reactor concepts that use beryllium moderators can anticipate gains in breeding ratio from the $(n,2n)$ reaction in Be. According to independent calculations by W. Haefele (ORNL and Karlsruhe, W. Germany) and J. Chernick (BNL), this reaction can mean a net gain in breeding ratio of 0.06, even after the neutron losses to the competing Be(n,α) reaction. The reaction product Li^6 may drop this gain to 0.02 when it reaches equilibrium concentration.

Doubling defined. The conference revealed that the term "doubling time" (the time required to double the inventory of fissionable material associated with a reactor) is ambiguous. For instance, the doubling time for a whole system of reactors in which new fissionable material is pooled to start up individual new reactors as soon as enough is available is only 70% of that for a single isolated reactor. Also authors have assumed plant load factors ranging from 0.7–1.0. H. G. MacPherson (ORNL) suggests that the term be standardized to mean the number of years a single reactor must operate at full power to double its associated inventory; this number, at the same time, would be nearly equal to the doubling time of a large complex of reactors operating at 70% plant factor.

* * *

The above report is based on material from the summary address at the conference by J. R. Dietrich (GNEC) and a report prepared by H. G. MacPherson (ORNL).

Rough Surfaces Up Burnout Point

Tests on water-cooled annuli show that roughening the heat-transfer surfaces increases the burnout heat flux by 50–100% over that for smooth surfaces at the same coolant velocity, temperature and pressure. By simultaneously roughening the surfaces of a reactor fuel assembly and enlarging the coolant passages, one could realize a net gain of as much as 80% in heat flux at burnout without increasing pumping power. The test tubes were roughened by machining knurls or threads to a depth of 5–13 mils. Tests were conducted for annuli thicknesses of 0.12–0.25 in., coolant velocities of 10–28 ft/sec and a pressure of about 50 psia. (W. S. Durant and S. Mirshak, DuPont DP-380)

BREEDING *(Continued from p. 66)*

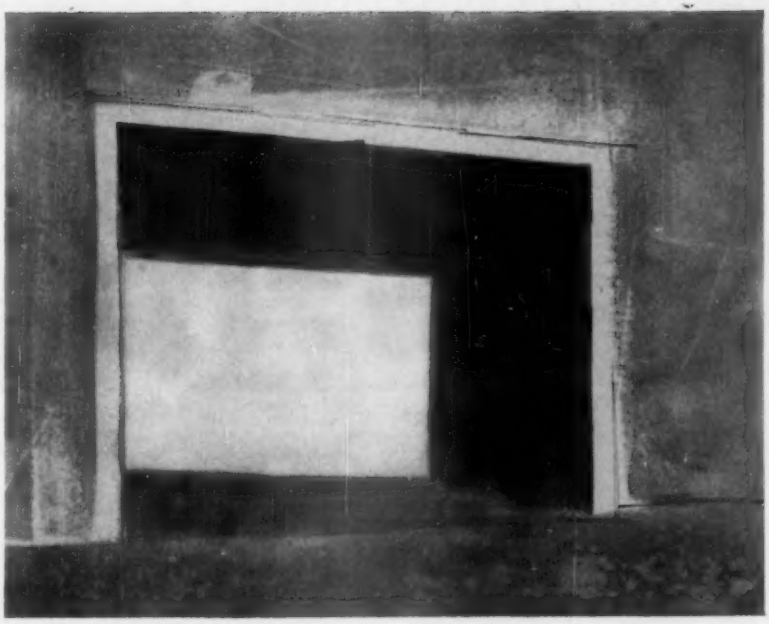
Thorium cannot influence uranium consumption significantly in the near term, when *inventory* of fissionable material must be a large fraction of the total demand. Eventually, the use of thorium in high-conversion-ratio cycles —or in breeders—can help to limit the increase in demand for uranium.

Qualitatively the first three items can be expected either to offset each other or to leave a net excess of supply. Canada and South Africa each have uranium reserves equal to or greater than those of the U. S.* (*20*).

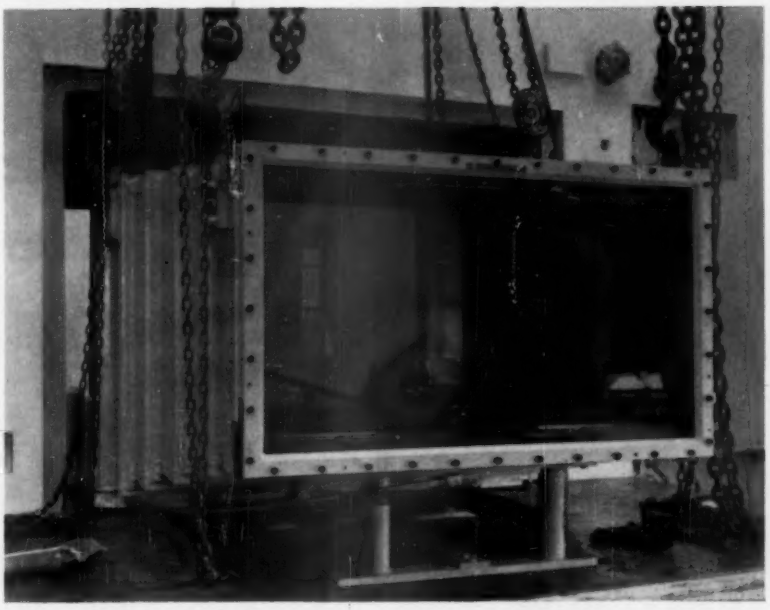
BIBLIOGRAPHY

1. E. Ayres. The fuel situation, *Sci. American* **195**, No. 4, 43, October, 1956
2. H. Brown, "The Challenge of Man's Future" (Viking Press, New York, 1954)
3. Estimated future power requirements of the United States 1955–1980, FPC-30, December, 1956; FPC-31, April, 1958, revised June 13, 1959 (Federal Power Commission)
4. P. C. Putnam, "Energy in the Future" (D. Van Nostrand Co., Princeton, N. J., 1953)
5. G. B. Warren, Trends in electric power generation costs, General Electric Co. Publication GER-1498 (1958)
6. E. Ayres, C. Scarlott, "Energy Sources, the Wealth of the World" (McGraw-Hill Book Co., Inc., New York, 1952)
7. J. C. Johnson, Geneva paper P/1921 (1958)
8. A. P. Butler, Geneva paper P/1904 (1958)
9. Atomic energy facts, Nuclear Technology Series (Government Printing Office, Washington, D. C., September 1957); also Domestic uranium production statistics for first half of 1959, AEC release, Sept. 9, 1959
10. W. E. Pratt; also the Department of the Interior, chapters in "McKinney Report to the Joint Committee on Atomic Energy," vol. II (Government Printing Office, Washington, D. C., January, 1956)
11. "Minerals Yearbook for 1954," vol. II, Bureau of Mines Publication (Government Printing Office, Washington, D. C., 1958)
12. H. Brown, L. T. Silver, Geneva paper P/850, vol. 8 (1956)
13. K. Cohen, "The Theory of Isotope Separation," NNES III-1b (McGraw-Hill Book Co., Inc., New York, 1951)
14. P. Greebler, W. Harker, W. Harriman, E. Zebroski, Geneva paper P/2167 (1958)
15. A plutonium fuelled fast breeder atomic power plant, APDA-129 (Atomic Power Development Associates, Detroit, Apr. 2, 1959)
16. Boiling water reactor study, TID-8500 (July, 1959)
17. W. K. Davis, L. K. Roddis, AEC release, Mar. 14, 1957
18. Development, growth & state of the atomic energy industry (202 Hearings, Joint Committee on Atomic Energy, Feb. 17–26, 1959), p. 515 (Government Printing Office, Washington, D. C., 1959)
19. Ref. 18, p. 105
20. AEC release Dec, 1959 "U statistics report"; also S. W. Clarkson. Uranium in the western world, AECL-858 (July, 1959)
21. K. P. Cohen, NUCLEONICS **16**, No. 1, 66 (1958)
22. P. Averitt, L. R. Berryhill, D. Taylor, Geological Survey Circular 293, p. 41 (U. S. Geological Survey, Washington, D. C., 1953)
23. D. P. Granquist. A calculation of the reactivity worth of plutonium and U-235 as enrichment in thermal reactors, Document HW-59758 (Mar. 27, 1959)
24. B. J. Toppel, R. Avery, *Trans. Am. Nuclear Soc.* **2**, No. 2, 149 (November, 1959)
25. P. Sporn, Testimony before the Joint Comm. on the Economic Rep. (Oct. 1959)
26. AEC 10-Year Program Survey, Part II, Summarized Nov. 3, 1959 at the A.I.F.

* Considering only ores workable at near-current prices.



You leave a hole in the hot cell . . .



We'll fill it with the right window

When you need a window for a hot cell, just tell us the wall thickness and energy level you're working with and the viewing area you want.

Leave the rest to us. We provide *all* calculations, designs, and materials, and deliver a packaged window that is ready to install.

We make the complete window . . . from the glass up. We've put more than 300 of these windows into service, ranging from peepholes to nine-tonners.

For particulars on the glasses and designs we use, write for a copy of PE-51, 16 Crystal St., Corning, N. Y.

CORNING GLASS WORKS

CORNING MEANS RESEARCH IN GLASS

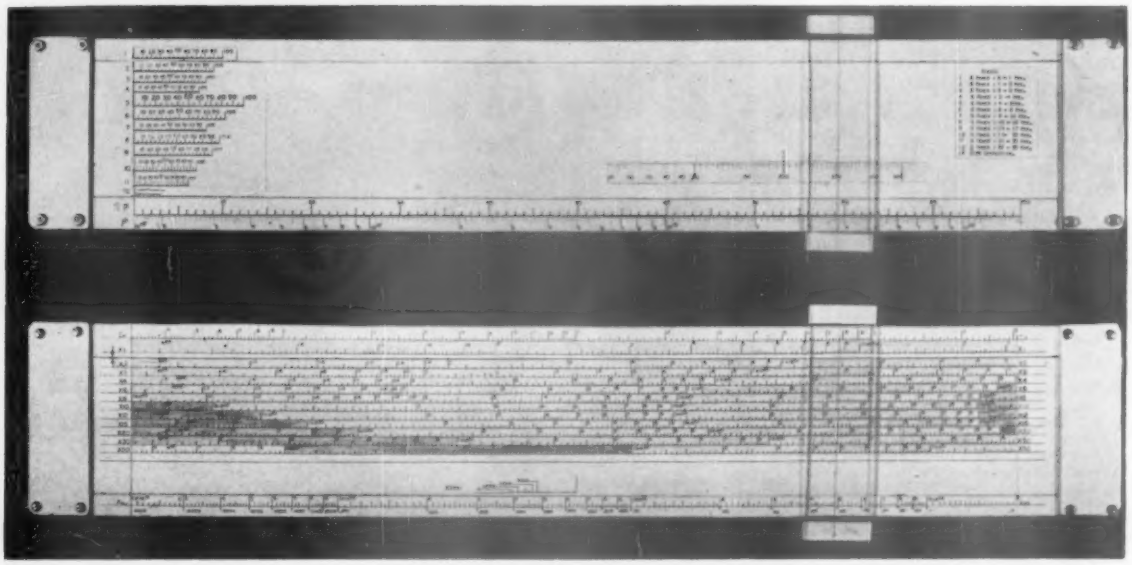


FIG. 1. XENON SLIDE RULE TELLS REACTIVITY VALUE of Xe^{135} when operator is ready to start reactor. Computation assumes instantaneous shutdown and requires history of last 50 hr of operation before shutdown occurs

Slide Rule Simplifies Xenon Computations

By DAVID E. DICKEY and JOHN E. McEWEN, Jr.
Westinghouse Electric Corp., Pittsburgh, Pennsylvania

After a reactor shutdown the operator wants to know the reactivity worth of fission-product poisons before restarting. The main part of the problem is that due to Xe^{135}, which builds up from decay of I^{135}, reaches a maximum about 9 hr after shutdown and then decays. One of three methods is usually used to compute the reactivity value of the Xe^{135}: (a) hand solution of the differential equations describing Xe^{135} formation and reactivity change, (b) analog solutions of the equations with electronic computers (*1*) and (c) reference to a family of curves.

We use instead a slide-rule nomograph to determine reactivity change caused by xenon after a reactor shutdown. The scales have been made general so that they can be used for any reactor. Where necessary scales have been calculated for a specific constant and a conversion scale provides for reactors with different constants.

The rule provides operating personnel with a simple device requiring little technical background. Its accuracy is 1–2%, which compares favorably with other methods. A rule of this type can be constructed of printed plastic or even cardboard at little cost. Figure 1 shows one model we have made.

Buildup of Xe^{135}

The differential equations for formation and decay of Xe^{135} and I^{135} in a reactor are as follows (see table of symbols, page 92)

$$\frac{dX}{dt} = \lambda_I I + \gamma_X P - \sigma_X X\phi - \lambda_X X$$

$$\frac{dI}{dt} = \gamma_I P - \lambda_I I \qquad (1)$$

Assuming P and ϕ constant, we can solve for $X(t)$ and get

$$X(t) = \frac{(\gamma_I + \gamma_X)P}{\lambda_X + \sigma_X\phi} + \left[X_0 - \frac{\gamma_X P}{\lambda_X + \sigma_X\phi} + \frac{\lambda_I\gamma_I P}{(\lambda_X + \sigma_X\phi)(\lambda_X + \sigma_X\phi - \lambda_I)} - \frac{\lambda_I I_0}{\lambda_X + \sigma_X\phi - \lambda_I} \right] e^{-(\lambda_X + \sigma_X\phi)t} + \frac{\lambda_I I_0 - \gamma_I P}{\lambda_X + \sigma_X\phi - \lambda_I} e^{-\lambda_I t} \qquad (2)$$

(*Continued on p. 90*)

SIGNIFICANT SOVIET RESEARCH IN NUCLEAR ENERGY REPORTED IN CB'S NEWEST TRANSLATIONS . . .

A must for Scientists and Engineers concerned with Reactor Design, Nuclear Power, and Instrumentation . . .

LIQUID-METAL HEAT TRANSFER MEDIA

by S. S. Kutateladze, V. M. Borishanskii, I. I. Novikov and O. S. Fedynskii

The copious data on the study of heat removal by liquid metals obtained during the last 10 years in the Soviet Union and elsewhere are systematized and generalized by Soviet experts concerned with the problems that arise in the use of liquid-metal coolants in nuclear reactors. This comprehensive handbook will be extremely useful to scientists and engineers working in reactor design and nuclear power, and also those concerned with other fields where liquid-metal coolants can be utilized.

cloth illustrated $22.50

Electronic Techniques used by Soviet Pioneers in the field of . . .

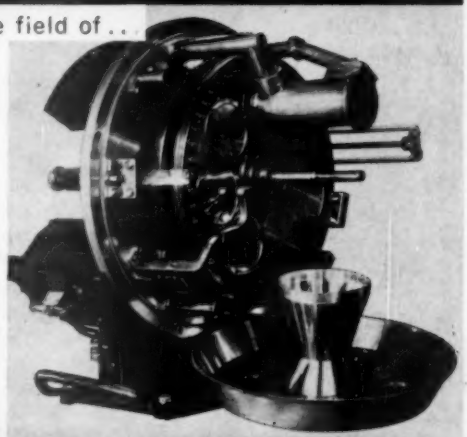
FAST-NEUTRON SPECTROSCOPY

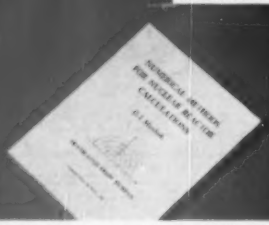
by B. V. Rybakov and V. A. Sidorov

These Soviet pioneers in the field present a comprehensive survey of the currently important methods of fast-neutron spectroscopy. Main emphasis is naturally given to the time-of-flight method. The authors describe in detail the electronic techniques used in fast-neutron spectroscopy (0.3-30 Mev), including description of their own experiments and the results obtained with the one and one-half meter cyclotron.

The experience reported here has already been used in the Soviet Union for design and construction of new cyclotrons, and this significant first Soviet monograph on the time-of-flight method will be an invaluable aid for engineers and physicists concerned with neutron physics.

cloth illustrated $17.50





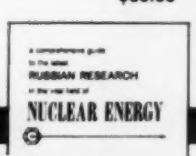
Emphasizes practical applications . . .

NUMERICAL METHODS FOR NUCLEAR REACTOR CALCULATIONS

by G. I. Marchuk

A comprehensive discussion of the fundamental problems involved in using numerical methods for nuclear reactor calculations, with emphasis given to various practical applications. Will be of special value to graduate students in physics, doctoral candidates, engineers and scientific workers specializing in this type of calculation.

durable paper covers
illustrated
$60.00



PRODUCTION OF ISOTOPES

This comprehensive work, consisting of eighteen papers, originated at the All-Union Scientific and Technical Conference on the Application of Radioactive Isotopes, Moscow, 1957. The papers report on the problems and achievements in production of radioactive isotopes by irradiation of targets in Soviet reactors and cyclotrons. Not only is this work of significance to producers of isotopes, but many of the papers will prove useful to isotope users as well.

durable paper covers illustrated $50.00

Now Available... A comprehensive catalog of our titles in the Nuclear Sciences...write now for your copy!

Order from your local bookseller or direct from:

CONSULTANTS BUREAU, INC.
227 WEST 17TH STREET, NEW YORK 11 N Y

This article starts on page 88

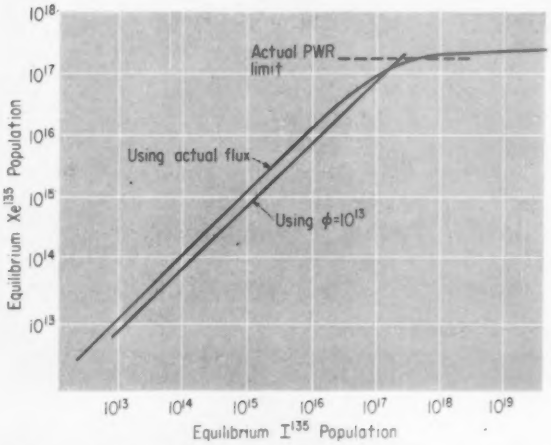


FIG. 2. APPROXIMATE AND ACTUAL relations between equilibrium populations of Xe^{135} and I^{135} as given by Eqs. 3 and 8

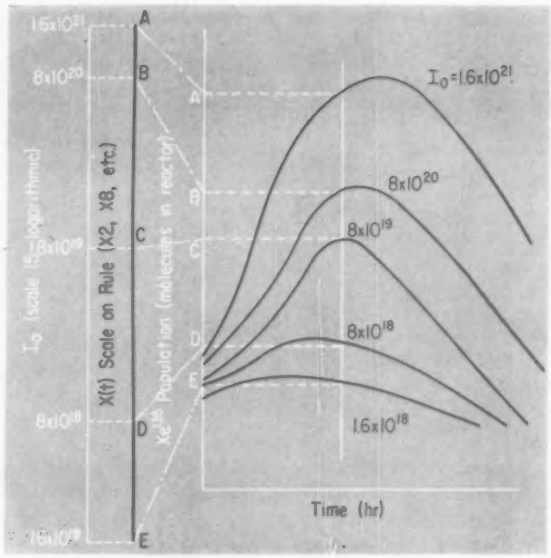


FIG. 3. CONSTRUCTION OF $X(t)$ scales from buildup and decay curves permits evaluation of Xe^{135} as a function of time

For equilibrium concentrations of Xe^{135} and I^{135}, we set dX/dt and dI/dt equal to zero in Eq. 1 to get

$$I_e = \frac{\gamma_I}{\lambda_I} P \quad \text{and} \quad X_e = \frac{(\gamma_X + \gamma_I)P}{\lambda_X + \sigma_X \phi} \qquad (3)$$

Equation 2 is an explicit expression for the quantity of Xe^{135} at any time. To get usable, finite solutions, one must put boundary conditions on P and ϕ. The first is suggested by the fact that the quantity we want is the amount of Xe^{135} after a shutdown. We assume that P and ϕ go suddenly to zero. This is not exactly true, for even a subcritical reactor has a finite flux. But the subcritical flux is usually of the order of 10^5 n/cm²/sec when operating values are 10^{13} n/cm²/sec. Moreover the times of interest in Eq. 2 are usually stated in hours whereas flux and power are usually reduced by a factor of 10^3–10^5 in a matter of seconds or minutes during a shutdown. Thus we solve Eq. 2 for a step function ($\phi = \phi$, $P = P$ at $t = 0^-$; $\phi = 0$, $P = 0$ at $t = 0^+$), and the result is

$$X(t) = X_0 e^{-\lambda_X t} + \frac{\lambda_I}{\lambda_I - \lambda_X} I_0 (e^{-\lambda_X t} - e^{-\lambda_I t}) \qquad (4)$$

Determination of Xe^{135} concentration at any time t after a reactor shut-

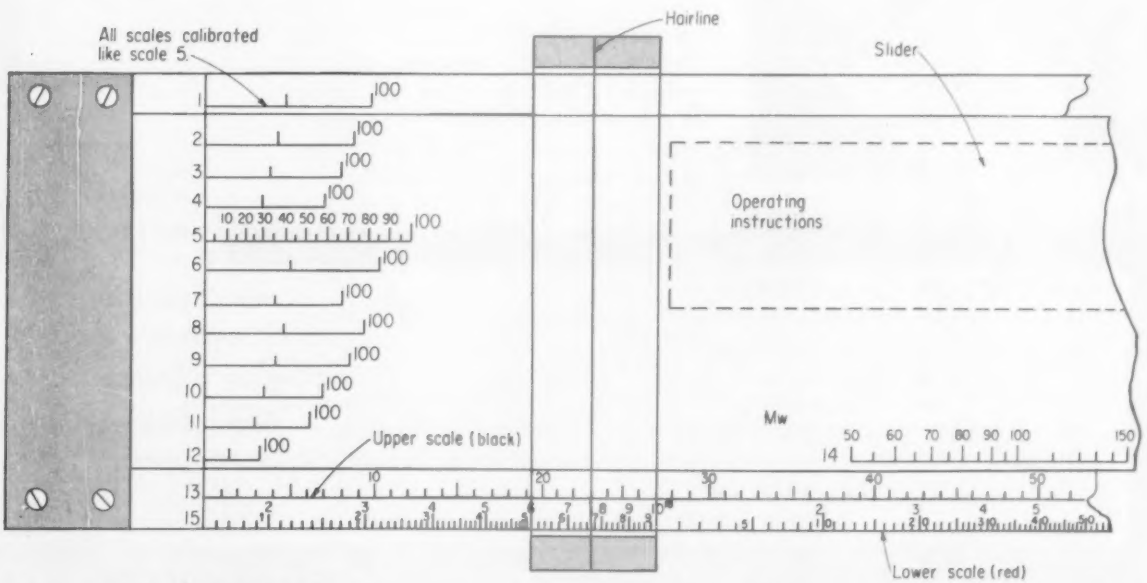


FIG. 4. SCALES ON FRONT OF RULE integrate over reactor history (Scales 1–12) to give I^{135} at shutdown (Scales 13, 15) and correction for actual power of reactor if actual power is not the reference value of 200 Mw (Scale 14)

SCINTILLATION CRYSTALS

Sodium Iodide (Tl)
Lithium Iodide (Eu) (Li^7 and Li^6)
Cesium Iodide (Tl)
Stilbene • Anthracene
Plastifluor® Plastic Scintillator

Available Unmounted or Mounted
and Hermetically Sealed

STABLE ISOTOPES

Carbon 13 • Nitrogen 15
Boron 10 and 11
Deuterium • Oxygen 17 and 18

Highest Enrichment and Purity
Wide Variety of Labeled Compounds

Write for free literature.

Isomet
CORPORATION

421 Commercial Ave.
Palisades Park, N. J.

NOW!

a pulsed neutron generator for less than $5,000.00

OMNITRON

shown mounted in use.

Greatly increases research capabilities of sub-critical assemblies and training reactors. Allows demonstration of fusion reactions and neutron counting techniques, makes radio isotopes and studies transient behavior of neutrons. Is simply constructed, compact, portable. Requires no special installation or power facilities. Five different models available.

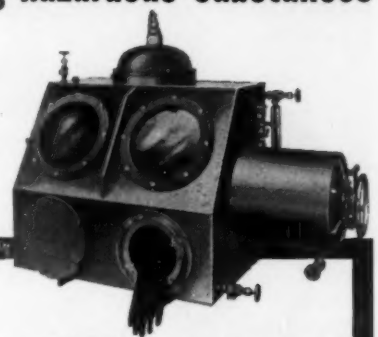
Prices start at $4,950.

cenco®

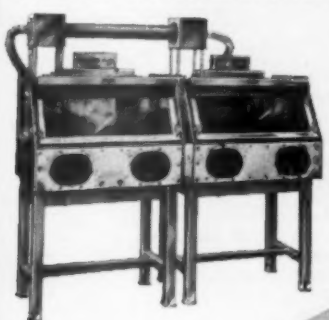
CENTRAL SCIENTIFIC CO.
A Subsidiary of Cenco Instruments Corporation
1736 Irving Park Road • Chicago 13, Illinois
Branches and Warehouses — Mountainside, N. J.
Boston • Birmingham • Santa Clara • Los Angeles • Tulsa
Houston • Toronto • Montreal • Vancouver • Ottawa

22 types of SAFETY ENCLOSURES for handling hazardous substances

VACUUM DRY BOX
for work in controlled atmosphere • sloping front • round autoclave-type air lock.

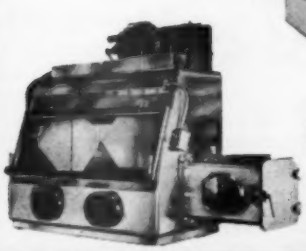


Safety is the first consideration in this newly-designed stainless steel laboratory equipment. These enclosures make it safer—and easier—for the technician to work with contaminants, micro-organisms, live viruses, infected animals, poisonous and radioactive substances. Stainless steel constructed with crevice-free surfaces, generously rounded corners, for easy cleaning and decontamination. Write for illustrated folder describing 22 different kinds of enclosures. S. BLICKMAN, INC., 7902 GREGORY AVENUE, WEEHAWKEN, N. J.



UNITIZED ENCLOSURES
Low in cost • Stainless steel • Modular construction adapts to many uses.

CALIFORNIA-TYPE FUME HOOD
For handling radioactive materials • dual-sided for double operation.



MICRO-BIOLOGICAL SAFETY CABINET
Back or top mounting of biological filter canister • air lock if wanted.

BLICKMAN SAFETY ENCLOSURES

Look for this symbol of quality Blickman-Built

Optical instrumentation for accurate measurement of remote or inaccessible objects

Gaertner M901 General-purpose Cathetometer

CATHETOMETERS

Gaertner Cathetometers are designed for accurate measurement of vertical distances or displacements. They are ideally suited for measuring where the object or action is remote or not accessible by ordinary means. Gaertner produces a wide variety of precision-constructed cathetometers to meet your individual requirements.

- **General-purpose Cathetometers**—These combine a high degree of accuracy with a maximum of convenience. Range 100 cm, focusing range 60 cm to infinity.
- **Precision Cathetometers**—For maximum accuracy and rigidity. Readings directly to 1 micron.
- **Micrometer Slide Cathetometers**—For precise measurement of short vertical distances. Range up to 4" or 100 mm. With telemicroscope, focusing range 12 cm to infinity.
- **Co-ordinate Cathetometers** — Permit making precise co-ordinate measurements on objects in a vertical plane. Focusing range 9" to infinity. Co-ordinate measuring range up to 24"x42".

SPECIAL PURPOSE PERISCOPES
REMOTE OPTICAL STRAIN MEASURING INSTRUMENTS

Write for Bulletin 162-56

The Gaertner Scientific Corporation

1257 Wrightwood Ave., Chicago 14, Ill.
Telephone: BUckingham 1-5335

down is reduced to finding X_0 and I_0 in Eq. 4. In the special case of a reactor operated for a long time (>50 hr) at constant power before shutdown, these are the equilibrium values of Eq. 3. In other situations one must perform an integration over the recent power history.

Values of X_0 and I_0

Equation 1 shows that I_0 is a function of the power history of the reactor before shutdown. For each fission occurring in the reactor there is probability γ_I that an I^{135} atom will be produced. Thus during an interval Δt_i at a time t_i before shutdown the following amount of I^{135} is produced:

$$\Delta I(t_i) = \gamma_I P(t_i)\, \Delta t_i \qquad (5)$$

At the later time $t = 0$ this I^{135} will have decayed to the following value (t_i is measured *backward* from the moment of shutdown, $t = 0$):

$$\Delta I_0(t_i) = \gamma_I P(t_i)\, \Delta t_i e^{-\lambda_I t_i} \qquad (6)$$

Summing both sides of Eq. 6 over the power history, one can compute I_0 as follows:

$$I_0 = \gamma_I \sum_i P(t_i)\, e^{-\lambda_I t_i}\, \Delta t_i \qquad (7)$$

The summation can be limited to 50 hr prior to shutdown. I^{135} has a 6.7-hr half-life; so only 0.5% of the I^{135} formed 50 hr before shutdown is still present.

By similar reasoning one can develop an estimate of X_0. However, since the contribution of X_0 is much smaller than that of I_0, it is a good enough approximation to take X_0 as a function of I_0. We develop a graph showing equilibrium values of the two populations X_e and I_e for different reactor power settings and assume that X_0 and I_0 are always related to each other in this way.

For an approximate value of X_e we use Eq. 3. This equation is complicated by the presence of ϕ in the denominator. However, reactor power requires a neutron flux in a limited range, and a nominal, constant value of ϕ can be used to make the denominator a constant without introducing objectionable error. We use a nominal value of $\phi = 10^{13}$ n/cm²/sec so that $X_e = KP$, where

$$K = \frac{\gamma_I + \gamma_X}{\lambda_X + 10^{13}\sigma_X} \qquad (8)$$

For a flux greater than 2×10^{14} n/cm²/sec, X_e becomes essentially independent of ϕ. Figure 2 compares this approximate solution with the actual variation of X_e with I_e.

Using the Rule

The first manipulation with the slide rule is designed to calculate the summation of Eq. 7 ($\Sigma P e^{-\lambda t}\, \Delta t$). Figure 4 shows how it is done. This portion of the rule is calibrated in terms of per cent of full power. Thus it is general and can be used for any reactor.

The 50-hr period before reactor shutdown is divided into 12 convenient intervals (Δt_i) and each of the 12 short scales corresponds to one of the intervals. Each of the short scales is calibrated linearly from 0 to 100%. The sum of the lengths of these scales is equal to the length of Scale 13, which in turn is linearly calibrated from 0 to 100%.

The reactor operator uses each of the 12 scales in turn. He must know the average power level of the reactor for each of the 12 time intervals. (For example, for Scale 12 he must know the average reactor power for interval 12, which is 50–30 hr prior to reactor shut-

Symbols

- ϕ = thermal-neutron flux (n/cm²/sec)
- Σ_f = macroscopic fission cross section of fuel
- P ($= \Sigma_f \phi$) = fission rate (fissions/sec)
- X = number of Xe^{135} atoms in reactor
- I = number of I^{135} atoms in reactor
- σ_X = microscopic absorption cross section of Xe^{135}
- γ_X = probability of Xe^{135} atom being produced in fission (0.003 per fission)
- γ_I = probability of I^{135} atom being produced in fission (0.056 per fission)
- λ_X = radioactive decay constant of Xe^{135} (2.1×10^{-5} sec^{-1})
- λ_I = radioactive decay constant of I^{135} (2.9×10^{-5} sec^{-1})
- Σ = macroscopic absorption cross section averaged over reactor (cm^{-1})
- V = reactor volume

Subscripts

- e ~ equilibrium values at constant power P
- 0 ~ values at zero time (the instant of reactor shutdown)
- F ~ fuel
- M ~ structural materials and moderator

down.) He places the hairline over the average power during each interval and reads the number that falls under the hairline on Scale 13. This number is the per cent equivalent I^{135} contribution. The sum of the 12 numbers is the value of I_0 expressed as a percentage of the value that I_0 would have if the reactor were operated at full power for all of the 50 hr before shutdown. (The decay time used in the exponent is from the middle of the appropriate interval to the moment of shutdown.) Since Scales 2–12 are on the slider of the rule and Scale 13 is on the frame, the addition can be performed by successively moving slider and hairline rather than by writing down the 12 individual values.

In designing the rule one computes the correct length of each of the 12 small scales as follows:

$$L_i = \frac{L_{13} e^{-\lambda_I t_i} \Delta t_i}{\sum_{i=1}^{12} e^{-\lambda_I t_i} \Delta t_i} \qquad (9)$$

For example, the length of Scale 1 (Fig. 4) on our rule is

$$L_1 = \frac{(10 \text{ in.})(1 \text{ hr})(e^{-\lambda_I \frac{1+0}{2}})}{9.47 \text{ hr}} = 1.003 \text{ in.} \qquad (10)$$

Scale 15 is designed for calculating I_0 in a 200-Mw reactor from the equivalent percentage read from Scale 13, and Scale 14 is designed for correcting this quantity for reactors that have power ratings greater or smaller than 200 Mw. The procedure is as follows: Read the per cent equivalent I^{135} from Scale 13. Place the hairline over this number on the upper half of Scale 15. If the reactor has a full-power rating of 200 Mw, read I_0 from the lower half of Scale 15. If it has a different power rating, move the slider to put the 200 Mw of Scale 14 under the hairline; move the hairline to the reactor power rating; read I_0 from the bottom half of Scale 15. Both Scale 14 and the bottom half of Scale 15 are logarithmic; so the correction to powers higher or lower than the nominal 200 Mw is a simple matter of scale addition.

Xenon and Time

The value of I_0 dictates a corresponding value of X_0 from Fig. 2, and the two together dictate an $X(t)$ curve from Eq. 4. The 12 scales on the back of the rule are designed to represent these $X(t)$ curves for 12 times after shutdown. The times are chosen so that linear interpolation is accurate for times that do not correspond to those of the scales.

As an example, suppose the reactor has been shut down for 8 hr. One places the hairline at the value of I_0 on Scale 15 and reads the value under the hairline on Scale X8 at the back of the rule to find $X(t)$. If the reactor has been shut down for 7 hr, he performs the calculation for 6 hr and 8 hr on Scales X6 and X8 and averages the two results for the 7-hr value.

Figure 3 shows the manner in which the scales for $X(t)$ are prepared. One starts with a family of curves for X as a function of t for different values of I_0. At the extreme left is the logarithmic Scale 15, which represents I_0. A vertical line intersects the family of curves at the time for which a scale is being prepared. Horizontal dotted lines from the intersection points determine the values of X that correspond to various values of I_0, and these numbers are transferred to their proper positions on the $X(t)$ scale, shown in Fig. 3 as the second vertical scale from the left. We have chosen times for our $X(t)$ scales such that the segments cut off on the curves of Fig. 3 are approximately straight. This means that the complete spectrum of values of X as a function of both I_0 and t is covered by either direct reading or linear interpolation.

Reactivity Values

The reactivity value of the Xe^{135} population X is equal to the fraction of all reactor neutrons that are captured in Xe^{135}. In other words one can write (see table of symbols)

$$\delta k(t) = \frac{\Sigma_X(t)}{\Sigma_F + \Sigma_M + \Sigma_X(t)} \approx \frac{\sigma_X X(t)}{V(\Sigma_F + \Sigma_M)} \qquad (11)$$

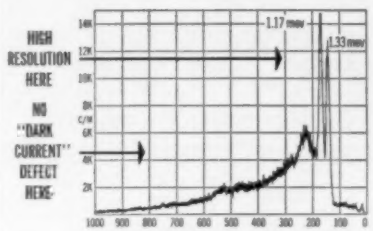
(We can drop Σ_X from the denominator since it is small compared with the other two terms.)

Both Σ's in the denominator of Eq. 11 are functions of the reactor design and Σ_F is also a function of the fuel burnup. Thus we write $\delta k(t) = C(t)X(t)$ and use two scales to make the computation. One scale gives δk as a function of X assuming a value for C $[= \sigma_X/V(\Sigma_F + \Sigma_M)]$ of 3×10^{-21} per molecule. The other is computed for the particular reactor to permit correcting for changes in C with burnup.

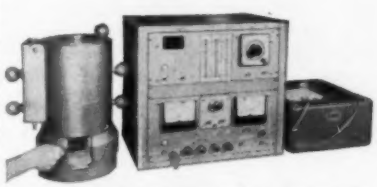
It is now possible to calculate $\delta k(t)$ on the nomograph using Scales 16, 17 and

This NMC Gamma Spectrometer Eliminates "Dark Current" Defect

Combines Better Resolution With Greater Precision Over Wider Range Than Any Other System At Any Price

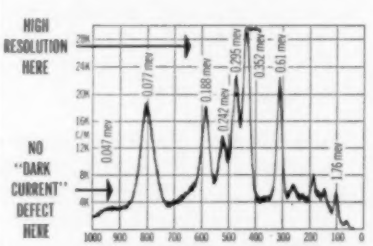


Actual spectrogram of Cobalt-60 made with a GSS-1. Window No. 3. Time constant: 2 sec.



A complete gamma spectrometer system NMC model GSS-1 ($4,180 fob, Indianapolis)

This greatly simplified system features regulated high voltage supply as part of the counting ratemeter auto-scan system . . . all-transistorized probe amplifier and spectrometer circuits . . . and solid or well-type crystal. These points and the actual spectrograms shown here tell only part of the story. For full details, write or phone collect.



Actual spectrogram of Radium made with a GSS-1. Four runs over a period of 20 hours with no adjustment of instrument between runs, demonstrating utmost stability. Range: 30,000 C/M. Time constant: 3 sec.

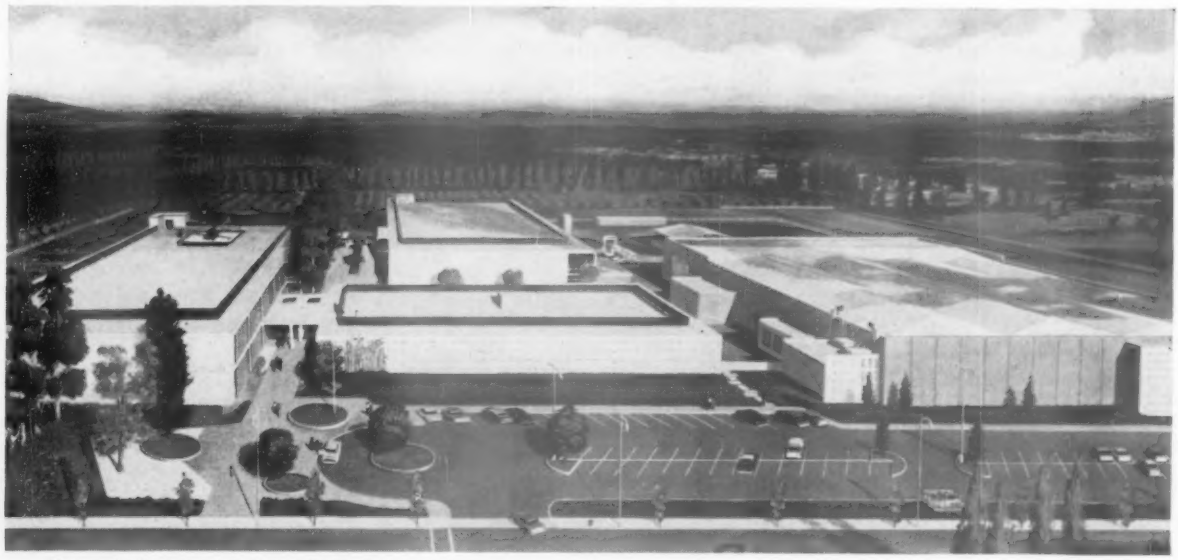
NMC

Nuclear Measurements Corp.

2460 N. Arlington Ave. • *Phone:* Liberty 6-2415

INDIANAPOLIS 18, INDIANA

International Office: 13 E. 40th Street, New York 16, N. Y.



New world-wide headquarters of Atomics International

Scientists and Engineers

Atomics International, a Division of North American Aviation, Inc., and a world leader in the peaceful applications of atomic energy, is now at home in its new international headquarters in the suburban San Fernando Valley of Southern California. This modern facility with its numerous laboratories for research and development is supported by AI's field laboratory in the Santa Susana Mountains, one of the finest experimental and test facilities in the industry. A wide variety of challenging new development projects now underway has opened outstanding opportunities for qualified scientists and engineers.

Fuel and Materials Development

Senior Metallurgist, Physical Chemists, Engineers

Reactor Materials: Research involves investigation and analysis of mechanical and physical properties of metallic alloys and inter-metallic compounds. Materials are to be used in power reactors for fuel, and fuel cladding, moderators, control rods, and structural members. Studies will include analysis of materials after exposure to high temperatures and radiation fields.

Fuel Element Engineering: Responsible for the complete analysis and design of fuel elements. This includes nuclear, thermal, material, mechanical and cost analyses. Should be familiar with fuel life determination methods and reprocessing techniques.

Fuel Fabrication: Activities will include development fabrication of materials and fuel elements, for both plate and rod forms and complex assemblies. A knowledge of non-destructive testing methods is essential, in addition to familiarity with a wide range of material processing and fabrication techniques.

Irradiation Experimentation and Hot Lab Evaluation: Senior Research Engineers and Physicists are required to design and conduct irradiation experiments on developmental materials including reactor fuels. The individuals must be familiar with a wide range of radiation and temperature conditions. Experimental conditions will include the simulation of conditions expected in full scale power reactors. Also senior personnel are needed to develop equipment and techniques required for the post-irradiation testing and evaluation of these experiments.

For specific details write: Mr. C. B. Newton, Personnel Office, Atomics International, 21600 Vanowen Street, Canoga Park, Calif.

ATOMICS INTERNATIONAL
A DIVISION OF NORTH AMERICAN AVIATION, INC.

RESEARCH OPPORTUNITIES

Solid State Chemists or Chemical Physicists: For basic research on nonstoichiometric and defect compounds. Interest or experience in one or more of the following techniques desirable:
High Temperature X-ray Investigations
Single Crystal Growth
Diffusion Studies
Electrical and Magnetic Measurements
Determination of Phase Diagrams
Theoretical Studies of Solids – statistical and quantum mechanics, lattice dynamics.

Theoretical Solid State Physicists: PhD required for research in the theoretical interpretation of lattice dynamics and the theory of energy transfer between solids and incident radiation. Also to work on the electronic band structure of metals and alloys, and the electronic structure of insulators.

Experimental Solid State Physicists: For research in following areas:
High Temperature Thermal Properties
Surface Physics and Chemistry
High Temperature Electrical and Thermal Properties
Optical Absorption
Sintering and Diffusion

Radiation Chemist: Senior physical or physical-organic chemist capable of taking problem all the way from conception to publication for fundamental publishable research. Experience in the following areas desirable:
Vacuum Line Techniques
Kinetics
Free Radical Chemistry
Photochemistry
Organic Reaction Mechanisms

Theoretical Physicists: To improve methods of analyzing fast and epithermal reactors, to plan and analyze critical experiments and to relate current developments in nuclear physics to reactor physics.

Mathematicians: To work in numerical and mathematical analysis including boundary value problems for ordinary and partial differential equations, moving boundary value problems, and the application of Monte Carlo methods, relaxation methods, and noise analysis.

For specific details write:
Mr. C. B. Newton, Personnel Office, Atomics International, 21600 Vanowen Street, Canoga Park, California.

ATOMICS INTERNATIONAL
A DIVISION OF NORTH AMERICAN AVIATION, INC.

18. Scale 16 is an $X(t)$ scale to which one transfers the population of xenon that one got from the applicable $X(t)$ scale. Scale 18 is below it and multiplies the values of Scale 16 by 3×10^{-21}. This gives the reactivity change due to xenon in a representative core. Scale 17 is calibrated in terms of a burnup parameter (for example, equivalent full-power hours) and multiplies the values read on Scale 16 by a burnup factor.

Procedure

Once the scales are established, a step-by-step calculation of δk due to Xe^{135} after a shutdown is as follows:

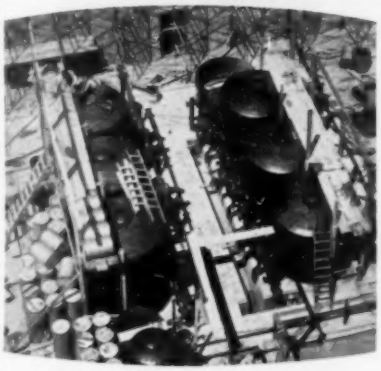
1. Get power history for 50 hr preceding shutdown from records.
2. Determine average power in each of 12 time intervals during those 50 hr.
3. Set hairline over number on Scale 1 that represents average reactor power (%) during first interval. Move slider to put index of Scale 2 under hairline.
4. Move hairline to number on Scale 2 that represents average power in second interval. Move slider so that zero of Scale 3 falls under hairline. Repeat Steps 3 and 4 for remaining 10 interval scales.
5. Read value of per cent equivalent I^{135} contribution from Scale 13. Move hairline to this number on Scale 15. Move slider so that 200 Mw on Scale 14 falls under hairline.
6. Move hairline to that number on Scale 14 that represents full power on reactor under consideration. I^{135} population at moment of shutdown now appears under hairline on Scale 15.
7. Turn rule to other side and move slider so that index lines at upper left coincide. (Do not move hairline.)
8. Choose scale that corresponds to time after shutdown and read $X(t)$ under hairline on that scale. (For example, if reactor is to be started up 10 hr after shutdown, use X10 scale. Interpolate as necessary.)
9. Move hairline to transfer value of $X(t)$ to Scale 16. Reactivity value in new core appears under slider on Scale 18. To correct for burnup, place index of Scale 17 under hairline and move hairline to burnup parameter (effective number of full-power hours) on Scale 17. Actual reactivity value appears under hairline on Scale 18.

BIBLIOGRAPHY

1. NUCLEONICS **16**, No. 10, 104 (1958)

PATHWAYS OF A PIONEER

ILLCO-WAY DESIGNERS AND BUILDERS
MODERN EQUIPMENT FOR ionXchange



This picture was taken in *1943* of a Continuous *600 gpm* IonXchanger during installation at a midwestern chemical plant. The tanks are shown being loaded with ionXchange resins.

Blazing the Trail for De-I Developments

When the photograph above was made, IWT already had well over 50 large industrial ionXchangers in successful operation — yet ion-exchange in those days was still considered a "new and untried" process! Many of these pioneering IWT installations are *in use today*, and most of the early users of IWT ionXchange have *added to* and *modernized* their equipment as new developments became available.

Even today IWT is still pioneering — adding to its great stock of knowledge in this specialized field, designing and building up-to-date ionXchangers of all types and sizes for application to a wide variety of processes as well as all kinds of water-treatment, experimenting with and carefully testing new ionXchange uses, and constantly improving existing designs.

THIS EXPERIENCE CAN MEAN A LOT TO YOU

If you need pure water for high-pressure boiler make-up or process use, or if you are considering the use of ion-exchange for purification or concentration of chemical products, be sure to take advantage of IWT pioneering experience and specialized knowledge. *Call your IWT representative.*

ILLINOIS WATER TREATMENT CO.
840 CEDAR ST., ROCKFORD, ILLINOIS
NEW YORK OFFICE: 141 E. 44th St., New York 17, N.Y.
CANADIAN DIST.: Pumps & Softeners, Ltd., London, Ont.

now more than ever

radiation monitoring you can bank on

new peace of mind comes to the wearer of this badge. Not only does he always know the full *score* on his personal exposure, but he can confidently rest on its *accuracy*, too. Continuous technical improvement in Gardray film processing and densitometry (direct electronic IBM recording now eliminates all possibility of human error) gives him this positive protection . . .

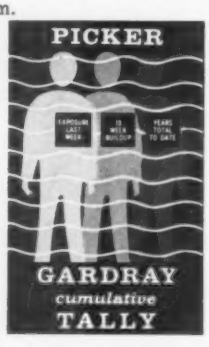
GARDRAY records exposures as low as 1 mr, as high as 300,000 mr.

GARDRAY is sensitive to gamma and x-radiations and beta radiation: reports them separately.

GARDRAY reports are cumulative tallies: (1) current week (2) 13-week total (3) year's total to date.

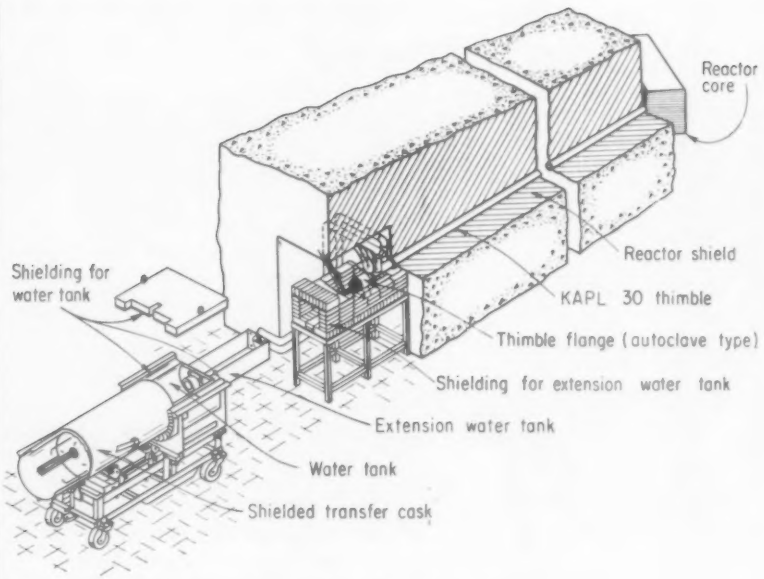
GARDRAY reports are prompt (two days in and out, average).

GARDRAY identification is doubly-sure: (1) printed on wrapper (2) x-rayed on film.



You can start enjoying this protection (and acquiring this peace of mind) any time. Right now, if you wish, by calling any Picker X-Ray local office. *Or write to*

PICKER
X-RAY CORPORATION
25 So. Broadway, White Plains, N.Y.



HOT-RELOADING FACILITY for the HB-1 position of the MTR

Hot Reloading of In-Pile Tests

By H. K. RUHL, *Knolls Atomic Power Laboratory, Schenectady, N. Y.*

Efforts to develop long-life power-reactor cores must include studies of long-term exposures of fuel materials. For maximum information, it is desirable to observe incremental irradiation effects several times throughout the exposure period. A considerable saving in reactor use time and in preparation of duplicate assemblies can be effected by making successive measurements on a single assembly. This approach involves unloading, examining and reloading a hot assembly and requires an assembly that can be disassembled and reassembled remotely. Here's how we did it for a horizontal beam hole at the MTR along with some suggestions on how to provide for hot-reloading in a vertical geometry.

Horizontal arrangement. A facility for hot reloading a blind, horizontal beam hole (shown in the illustration) was provided by KAPL for the HB-1 position of the MTR.

This facility is a redesigned, high-temperature, high-pressure, water-cooled test loop. Two changes were made: (a) The three flow tubes were arranged to provide a "straight shot" from the out-of-pile flange surface to the in-core end of the tube. (b) A previous problem of bypass flow leakage was eliminated by a deep-drilled header section at the out-of-pile end.

Shielding was the most difficult problem. Also, the test assembly must remain covered with water to prevent sample overtemperature due to excessive gamma heating.

Vertical arrangement. If experimental access to the reactor is from the top it should be possible to make use of the water within the tank as shielding. Under these conditions, a hot reloadable in-pile tube should provide:

1. An end-closure design at the top that can be operated remotely under water. Test assemblies can then be handled by suitable grapples and transferred to other underwater operating areas without exposing personnel.

2. A "straight-through" configuration within the tube from the closure to a point below the high-flux test length of the tube. This permits flexibility in designing the test section and allows inserting and removing the "test bundle" with the tube in the reactor.

NOW YOU CAN GET NUCLEAR FUEL "OFF THE SHELF"

Another example of M & C's special services for the Nuclear Industry

In the nuclear materials vaults here at M & C Nuclear are a wide assortment of shapes of varying nuclear metals ready for your immediate use.

As a leader in the field of nuclear fuel technology and with the greatest production experience of any privately owned nuclear fuel production facility, it is logical that M & C Nuclear would build a stock of foil, rod, wire and plates of uranium, thorium, alloys, and compounds. We will be glad to fill your order immediately and to offer our consulting service in the use of nuclear fuel elements from critical assembly to completed reactor. Texas Instruments Incorporated, M & C Nuclear, Inc. (a subsidiary), P. O. Box 898, Attleboro, Mass.

TEXAS INSTRUMENTS
INCORPORATED
M&C NUCLEAR, INC.
(A SUBSIDIARY)
P. O. BOX 898 • ATTLEBORO, MASSACHUSETTS, U. S. A.

The World's Largest Privately Owned Facility Designed Specifically for Fabrication-Development and Production of Fuel Elements, Core Components and Complete Cores.

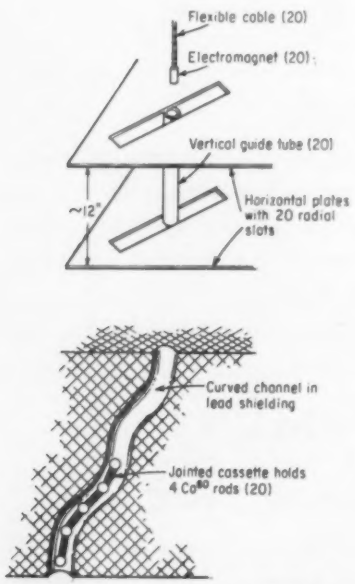
Editor in Moscow Sees

Russian Gamma Sources

By R. HOBART ELLIS, Jr.
Associate Editor, NUCLEONICS

EDITOR IN MOSCOW. NUCLEONICS Associate Editor Hobart Ellis (light coat) inspects Russian picture display of recent nucleonic accomplishments. Display was set up in front of Bolshoi Theatre, one block from Red Square, as part of celebration of October Revolution

Gamma facilities are a Russian specialty. Russian engineers are doing a lot of irradiation work; apparently all of it is done with gammas. [For one example see the story of woods improved with radiation-polymerized plastics, briefly in November (NU, Nov. 59, p. 184), in detail in next month's issue.] Irradiation specialists of the USSR have made many sophisticated gamma-source calculations. They are even now building a reactor in southern Russia that will use an indium-gallium loop as a gamma source. They are using several Co^{60} facilities of imaginative and sophisticated design.


Flexible cable (20)
Electromagnet (20)
Vertical guide tube (20)
~12"
Horizontal plates with 20 radial slots
Curved channel in lead shielding
Jointed cassette holds 4 Co60 rods (20)

IMAGINATIVE GAMMA FACILITY at Karpov Institute has Co^{60} rods in jointed cassettes that drop into lead shielding when not in use

Meanwhile the Russians show little interest in accelerators as radiation sources. One reason is their different set of economic standards. "The radionuclides cost nothing," they told one American who asked about costs at the Chicago Industrial Nuclear Technology Conference last September. Probably another reason is inertia. They are deeply immersed in radioactive-source technology; it is easier and more fun to keep on developing this.

Source Theory

A recent visit to the Karpov Institute of Physical Chemistry in Moscow infected me with the excitement that the Russians feel for irradiation technology in general and source design in particular. For a NUCLEONICS editor and NUCLEONICS readers the visit continues an old association. It started with a Ryabukhin and Breger article, discussed in our Russian Nucleonics column after it appeared in *Atomnaya Energiya* (NU, May '59, p. 178). The association continued when Ryabukhin himself appeared as one of seven Russians at the Chicago Industrial Nuclear Technology Conference last September (NU, Nov. '59, p. 184). Then Ryabukhin and Breger were my hosts as I visited gamma sources at the Karpov Institute and talked about projects that the source-design group is working on.

Ryabukhin's and Breger's *Atomnaya Energiya* article is a complex set of computations for reactor gamma sources. They apply quite generally to any nuclide produced in a reactor and used subsequently as a gamma source, including circulating-liquid loops.

On the basis of the calculations and some experiments, the source group at the Karpov Institute have decided that they can make a better gamma source—a reactor with an indium-gallium loop. Both of these metals are usable neutron-to-gamma converters (NU, July '57, p. 76), and together they form a eutectic with pleasant properties; corrosion is not the problem that it is with indium-sulfate loops.

Cobalt Facilities

Three Co^{60} gamma facilities were hard at work when I visited the Karpov Institute, and one more was going through its operational tests in preparation for installation of its cobalt. One source has 1,400 gram-equivalents; two have 20,000 gram equivalents; and the new one will have 60,000 gram-equivalents. (The Russians measure source activity in the radium gram-equivalent—the amount of a nuclide

that delivers a dose rate in air equal to that delivered by a gram of radium. A curie of Co^{60} is 1.6 gram-equivalents.)

The 20,000-gram-equivalent (12,500-curie) facilities operate with mechanical controls, a complex system of interlocks and a push-button delay circuit. The delay circuit is like those used frequently in the U. S. It might properly be called by the term "minuterie"—a French word referring to a switch that keeps a hall light on for about a minute while you get from the door of the building to the door of your apartment.

In the Karpov facilities an experimenter must inspect the cave, push the minuterie button inside the cave and then get out and close the door during a delay period of ~25 sec. With the door closed he can manipulate cranks on the outside to move the source shield under the experiment and raise the source into its irradiation position. Nothing has failed in a long period of operation, but provisions have been made to meet hypothetical emergency situations if controls break or freeze. Facilities permit experimenters on the floor above the cell to make measurements on irradiated samples during irradiations.

The new 60,000-gram-equivalent source is quite different from the older 20,000-gram-equivalent ones (see sketch). Stainless-steel-clad cobalt rods in jointed cassettes rest at the bottoms of 20 curved shielding channels when they are not in use. With an experiment in place, cables lower electromagnets into the channels, pick up the source cassettes and pull them up into 20 vertical guide tubes around the sample to be irradiated. The tubes are held between slotted horizontal plates that permit a variety of configurations. When I saw the installation the tubes were set in two parallel lines so that two intense slab sources would be created when the cassettes came up.

The arrangement gives an experimenter a maximum volume of 40 l and a minimum of 1.1 l. Maximum dose rate is 180,000 r/hr averaged over a volume of 0.1 l or 120,000 r/hr over a volume of 0.7 l. For smaller dose rates the experimenter can energize only some of the 20 electromagnets, leaving some cassettes at the bottom of the shield. Opening a magnet circuit allows the cassettes to fall to the bottom of the shield where a spring brakes the fall. No special cooling is required.

From *High Voltage Engineering Corporation* the most complete line of *supervoltage* and *high energy* radiographic equipment for

NON-DESTRUCTIVE TESTING AND EVALUATION OF REACTOR MATERIALS AND COMPONENTS

. . . 1 to 15 Mev X-Rays for high-speed, precise radiographic examination of special nuclear materials including high-density alloys, fuel elements, heat exchangers, pressure vessels, valves, control mechanisms *to meet rigid government inspection standards.*

SUPERVOLTAGE

- 1 and 2 Mev Van de Graaff X-Ray Generators
- Penetration: ½" to 11" equivalent steel thickness
- Mount Options: Fixed, truck, or flexible crane

Performance Characteristics

Model	Energy (Mev)	X-Ray Intensity 1 meter from source (r/min)	Focal Spot (mm)
JR	1	8	1
AR	2	75	1

Model JR, 1 Mev Van de Graaff x-ray generator used for inspection of fuel elements.

— Courtesy Babcock & Wilcox Co.

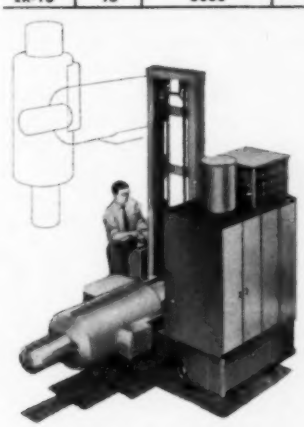
Write for 44-page technical paper: "High-Energy Radiography in the 6- to 30-Mev Range".

HIGH ENERGY

- 8-15 Mev Linac X-Ray Generators
- Penetration: 2" to 25" equivalent steel thickness
- Mount Options: Fixed, truck, or flexible crane

Performance Characteristics

Model	Energy (Mev)	X-Ray Intensity 1 meter from source (r/min)	Focal Spot (mm)
LR-8	8	1500-6000	1-5
LR-12	12	2300-18000	1-8
LR-15*	15	3000	1



8, 12, or 15 Mev High Energy microwave Linear Accelerator for radiography (truck-mounted).

**Designed for solid rocket propellant inspection.*

HIGH VOLTAGE ENGINEERING CORPORATION
BURLINGTON, MASSACHUSETTS • U.S.A.

Britons Open Pilot Plant to Try Radiation Processes

By JOHN TUNSTALL
McGraw-Hill World News
London, England

In the world's most elaborate irradiation facility Englishmen are now using 150,000 curies of Co^{60} to irradiate packaged products at an estimated 1.7¢/megarad-lb. The installation is at Wantage, six miles west of Harwell. Standardized packages move into the irradiation cell, shuffle back and forth on both sides of a single slab source and then move out onto an output rack.

Probably the most unusual feature of the design is its absorption efficiency; two racks on each side of the source are designed so that the source is completely blanketed by a double layer of packages with practically no spaces between them. Thus about 40% of the available radiation is usefully absorbed if the facility is loaded with packages of 0.5-gm/cm³ density. Dose varies by not more than 10% in any package. The estimate for the minimum absorption efficiency under worst loading conditions is 25%.

Cost estimates for the plant are based on a cobalt cost of $1.4/curie for specific activities of 1–3 curies/gm. The best U. S. price for such material is $2/curie. One reason for the cheaper cobalt in England is that the British Atomic Energy Authority uses cobalt as a flux flattener in the centers of reactor cores so that Co^{60} becomes a by-product. The price of $1.4/curie is based on production of cobalt in dual-purpose reactors; when civilian power-only reactors become available, it is hoped that Co^{60} can be priced as low as 35¢/curie.

High throughputs are recognized to be an important factor. The present facility is built to accomodate a 500,000-curie cobalt source at a later date. Estimates based on a facility to use a 1-million-curie source yield an irradiation cost half as great as that for the present installation.

Feed Mechanism

Figure 1 indicates the path of a package as it starts through the facility. Two process lines operate independently so that a small-dose process and a large-dose process can be going through the facility at the same time. One process occupies two inner racks, next to the source and separated from each other by two feet; the other occupies two similar racks, outside of the first set and separated from each other by four feet.

A package entering the facility comes through the shielding wall above the source and descends to the top shelf of a set of five that lie parallel to the source face. Then one head of a multiheaded ram pushes the package one package width along the shelf and withdraws to let the next package come into place. Thus the next stroke of the ram moves the package one more step across the shelf.

With repeated strokes of the ram the package moves across the top shelf until it comes to a movable platform at the end. The movable platform, suspended from a rocker arm, drops to the level of the second shelf, and another ram head pushes the package in repeated strokes across the second shelf in the direction opposite to that in which it moved across the first shelf. Each package pushes its neighbor so that each stroke of the ram pushes all of the packages on alternate shelves.

This shuffling motion continues until the package has made five passes

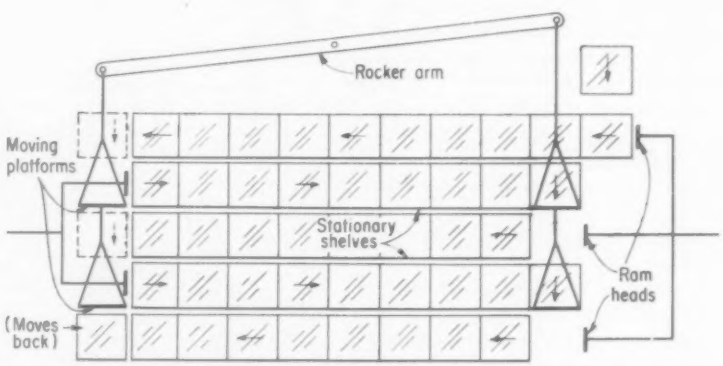


FIG. 1. SHUFFLING MOTION MOVES PACKAGES in front of slab source by combination of vertical motion (platforms) and horizontal motion (rams). Method eliminates spaces between packages and need for mechanisms and lubricants in cell

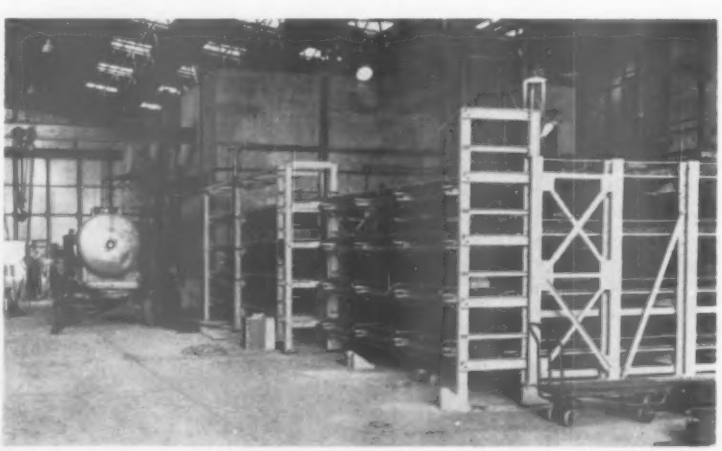


FIG. 2. INPUT RACKS stand side by side. Each holds 1,536 packages and automatically feeds them into conveyor leading to shuffling system of Fig. 1

If you are not subscribing to NUCLEONICS

- Use the handy card below to place your subscription
- YOUR OWN COPY INSURES UTMOST PERSONAL BENEFIT

Some Features of NUCLEONICS for 1960

1. Engineering of Reactor Cores and Primary Loops — updating current information on latest advances. A 24- or 32-page definitive report.
2. Exhibits and program of Atomic Exposition
3. How Radiation Affects Materials — a new look
4. Buyers' Guide (November)
5. Modern Tracer Techniques in Plant and Laboratory

SIMPLY MAIL COUPON BELOW

NOTHING TO PAY NOW
We will bill you after entry. Pay with order only if you prefer to do so.

NOTE TO PRESENT SUBSCRIBERS

This is not a notice for renewal if you are already subscribing. Card is intended only for new subscriptions. We shall appreciate your passing along this insert to one of your associates who might profitably subscribe.

NUCLEONICS, February, 1960

Enter my new NUCLEONICS subscription . . .

☐ FOR ONE YEAR, $8 ☐ FOR THREE YEARS, $16 (You save $8.)

_____SEND BILL LATER _____HERE'S THE MONEY

NU-

M-

2/60

PLEASE PRINT

Name: ..... Position.....

☐ Business Address:

☐ Home Address: .....

City: ..... Zone..... State.....

Company Name: .....

Nature of Nuclear Business or Service .....

MAIL AT ONCE . . . to start service promptly.

Foreign Rates (1 year) Canada $10, Latin America $10, Other $15

*This Special Card**

is your new subscription invitation

Reflecting the startling growth of the publication's field, NUCLEONICS in a few short **years has** gained the enthusiastic support of over 20,000 subscribers in all parts of **the world.** We invite you to join them.

Your own copy of NUCLEONICS each month insures your being in close, prompt contact with what is new and important affecting Nuclear Research; Nuclear Technology; New Uses of Radiation in the Sciences and Industry; Radiation Protection; Radiation Waste Disposal; Health Physics, Instrumentation; Atomic Power Progress; Reactor Technology; New Materials; New Equipment; New Publications; International Commercial Alliances; Atomic Power Politics—the shifts and changes—the facts behind the news.

SEND NO MONEY - - - See other side for handy coupon

*** Please note that offer is for new subscriptions only.**

NUCLEONICS February, 1950

FIRST CLASS
Permit No. 64
New York, N. Y.

BUSINESS REPLY MAIL
No Postage Stamp Necessary if Mailed in the United States

POSTAGE WILL BE PAID BY —

McGRAW-HILL PUBLISHING CO., Inc.

NUCLEONICS
330 WEST 42nd STREET
NEW YORK 36, N. Y.

Figures for the Plant

Irradiation cost	1.7¢/megarad-lb
Plant cost*	$21,000
Cobalt, cesium cost	$0.35–$1.4/curie
Maximum throughput (total installation)	7 megarad-tons/day
	12.5 tons/hr
	1,170 packages/hr
(inner machine)	900 packages/hr
(outer machine)	270 packages/hr
Transit time at maximum throughput	10 min
Package size	12 × 14 × 9 in.
Occupied target area†	11 × 5.5 ft
Source size	2 ft × 7 ft × 1.5 in.
Present source activity	150,000 curies
Maximum source activity	500,000 curies
Number of packages in irradiation cell	160
Capacity, each input rack	1,536 packages
Dose uniformity	±10%
Minimum dose	10,000 rads
Maximum dose (inner machine)	1.5×10^7 rads

* Without source; unofficial estimate.
† Area occupied by packages on each of four racks.

across the face of the source. Then the package moves to the other side of the source without turning and makes five similar passes across the second source face. After the tenth pass the package moves on an exit conveyor to an output platform.

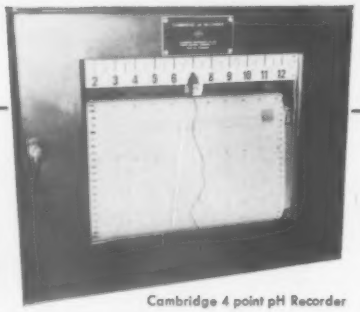
The main advantage of the shuffling motion is that it makes it possible to present a solid surface of packages to the source. A conventional conveyor system would require vertical separations between packages. The shuffling technique also has the advantage of nearly eliminating the need for mechanisms and lubricants in the radiation cell.

As each package is admitted at the head of a line it is used to push all the other packages along. A counting mechanism keeps track of every package in the cell and automatically shuts down the system if compressional displacements total more than half a package. Cams control the motions of the eight multiheaded rams so as to minimize accelerations.

Variable-speed hydraulic motors with speeds continuously variable over a ratio of 400:1 drive the shuffling mechanisms. The two systems can operate entirely independently, and they can work in series so that a package makes a total of twenty passes

FOR DEPENDABLE
HIGH-INTENSITY ILLUMINATION
KEMLITE LABORATORIES
USES "LINDE"
XENON
Lighting the way to safer aircraft landings is only one of many important uses for Kemlite Laboratories' new xenon-filled lamps. They are also used in missile-tracking, stroboscopic equipment, and the graphic arts, producing light intensities approximating zenith-position sunlight!
LINDE is a leading producer of rare gases which include xenon, krypton, argon, and neon. These are extracted through a unique liquefaction process pioneered by LINDE to meet the most rigid standards of purity for highly critical applications. For example, LINDE produces xenon of highest purity available, yet this gas exists as only one part in 12 million in atmosphere!
LINDE was first to produce many of the rare gases in wide use today. These are available in pure or mixed form. Mixtures can also be supplied with the radio-active isotope Krypton-85 as an additive.
For information, write Linde Company, Division of Union Carbide Corporation, Rare Gases Dept. NU-02, 30 East 42nd Street, New York 17, N.Y. In Canada: Linde Company, Division of Union Carbide Canada Limited, Toronto 7.
"Kemlite" Flash Lamp Type S-471
Linde
TRADE MARK
UNION CARBIDE
"Linde" and "Union Carbide" are registered trade marks of Union Carbide Corporation.

CAMBRIDGE HIGH PRESSURE pH RECORDER AT SHIPPINGPORT



Cambridge 4 point pH Recorder

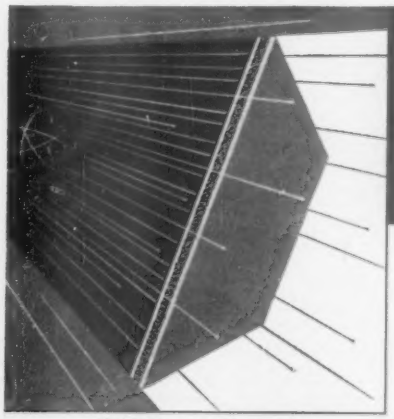
The Cambridge pH Recorder installed in this atomic power station utilizes specially designed analysis cells provided with gland electrodes suitable for operation under varying pressures up to several hundred p.s.i.

OTHER CAMBRIDGE INSTRUMENTS FOR NUCLEAR APPLICATIONS

There is a CAMBRIDGE Dissolved 02 Analyzer aboard the nuclear submarine SKATE. A CAMBRIDGE Dissolved H2 Analyzer served in preliminary work at the laboratory level at Shippingport. Cambridge also makes a Gamma Ray Pocket Dosimeter and the Lindemann-Ryerson Electrometer widely used in conjunction with ionization chambers.

CAMBRIDGE pH Meters and Recorders for standard applications are available. Send for bulletins describing instruments of interest to you.

CAMBRIDGE INSTRUMENT COMPANY, INC.
3555 Grand Central Terminal, N. Y. 17, N. Y.
PIONEER MANUFACTURERS OF PRECISION INSTRUMENTS



Sketch shows general construction.
As a B_4C dispersion in metal, Boral has predictable properties at elevated temperatures.

BORAL...
THE "SANDWICH" THAT SOLVES NEUTRON SHIELDING PROBLEMS

Boral is a uniform dispersion of boron carbide crystals in aluminum, with a cladding of commercially pure aluminum.

Boral is a very effective shielding material against the passage of thermal neutrons.

Any concentration of Boron Carbide up to and including 50% is now possible. Available from 1/16" thick to 3/4" thick in standard sizes of 30" x 48", 15" x 96", and 15" x 48". Other sizes on request. The approximate weight per square foot of 1/4", 35% Boral plate is 3.4 pounds.

TYPICAL and POTENTIAL APPLICATIONS

A. Reactor Shields
B. Neutron Curtains
C. Shutters for thermal curtains
D. Safety rods
E. Storage and shipping containers for fissionable material to avoid critical mass.
F. Fabricated boxes for electronic equipment and other radiation-sensitive devices.
G. Protective shields for easily activated components of aircraft, particularly engines.

Brooks & Perkins, the first commercial producer of Boral, invites you to send for technical data and literature.

BROOKS & PERKINS, INC.
1926 W. FORT STREET • DETROIT 16, MICHIGAN
Offices in Washington and New York

60-T-12

APPLIED RADIATION

This article starts on page 100

before the source faces, occupying all four sets of shelves in sequence.

Source

The source is a 2 × 7-ft slab matrix made up of 54 tubes each containing 24 cobalt rods. Before activation each rod is encapsulated in ¼-in.-diameter stainless-steel cylinders. Clusters of these cylinders went into stainless-steel canisters and then into the fuel channels of the Calder Hall reactor.

After activation the canisters were opened and cylinders regrouped according to specific activities. Variation in specific activities was as great as 100:1. The regrouped bundles then went into stainless-steel tubes for location in the slab matrix.

Cables suspend the source over a 15-ft-deep storage pool.

What For?

The installation is called a "pilot plant." It has been made optimal for sterilization and deinfestation of packaged products like medical and pharmaceutical supplies. The intention is to use it to make full-scale trial runs of radiation processes.

Wantage experts feel that the medical field has two conspicuous advantages to make it the most promising for radiation processes: (1) it has the most immediate economic potential for using large radiation sources; (2) its products are entirely compatible with packaging geometry required for efficient absorption.

And Cesium Too?

There are plans to test Cs^{137} as a source material in a cell that has been built back-to-back with the cobalt cell. Both cells are designed to hold 500,000 curies. There is little optimism, however, that cesium will prove to be more economical than cobalt.

The British feel that a curie of cesium will cost about the same as a curie of cobalt. Their new separation plant, now abuilding, will produce cesium at $1.4/curie to start, and this price will probably fall to 35¢/curie. Cesium has the advantage of longer half-life than cobalt and the disadvantage of less energy per disintegration. The British feel that the disadvantages outweigh the advantages and that irradiation costs with cesium (per megarad-pound) will be ~50% greater than they will be with cobalt.

Radiation Seeks Commercial Use

By S. EDWARD EATON, *Arthur D. Little, Inc., Cambridge, Mass.*

Radiation processes appear to be entering a new stage of development. A few are already known to be in active use; rumors indicate that others are in active use by people who don't want to talk about them yet. Many details of the picture came into view last September at the Warsaw conference sponsored by the International Atomic Energy Agency. This article and a second appearing next month discuss the aspects that appear most significant.

The conference program shows that many people feel that they are working on processes of practical value; it shows also that many feel the road to the practical is by way of the fundamental.

Many workers are searching diligently for the hows and whys of radiation effects; others are looking for new phenomena. They are finding a growing number of ways to get greater experimental yields of products, increases in specificity, lower costs and unique effects.

pH, Temperature, Pressure

The men at the frontier are trying most of the parameters of chemical engineering in their attacks on the barriers before them. Among the most promising are acidity, temperature and pressure. Control of acidity is being used to prevent undesirable side effects such as homopolymerization of monomer during grafting of methacrylic acid onto Nylon (*1*).

Russians have found that high temperature and pressure increase *G*-values for synthesis of phenol from benzene (*2*), cracking of *n*-heptane (*3*) and polymerization of ethylene (*4, 5*). It is not apparent that the gains are great enough to warrant plans for any commercial process, but the experimenters talk hopefully of results they expect from large-scale tests in the future.

High-pressure radiolysis (near the critical pressure of gases like ethane) has produced results indicative of ion-molecule reactions (*6*).

Low temperature has its advantages too, and predictions are frequently made that low temperature should increase radiolytic yields from exothermic reactions. Irradiation at low temperature may enable production of materials that are unstable at high temperatures—for example the peroxidation products of cumene and iso-octane (*7*). Ion-molecule reactions should be possible at low temperatures because they need little or no activation energy.

Next month the author discusses ion molecule reactions, irradiated catalysts and other aspects of the conference.

Diffusion Control

Experimenters are trying several methods for controlling diffusion of monomers and putting copolymers where they want them.

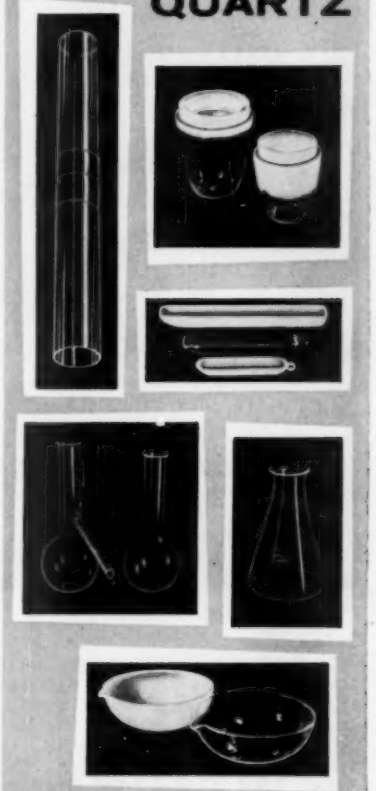
If you irradiate a Nylon fiber in vacuum or nitrogen and then irradiate it in a methanol solution of acrylamide you produce a graft copolymer on the surface only. This technique of preirradiation in vacuum, air or nitrogen is proving useful for controlling both depth and nature of graft copolymerization (*8*).

If Nylon is irradiated in air it is degraded. Subsequent immersion in acrylamide solution causes fibers to swell; acrylamide monomer diffuses into the inner layers of the fiber; irradiation grafts it to the fibers there.

Preswelling of fibers—without preirradiation—is being used to control the nature and extent of copolymerization. The technique leads to inner-layer graft copolymerization of styrene on cellulosic fibers of viscose when fibers are preswelled with a solution of 5% formamine in methanol and irradiated in a 50–75% solution of styrene in methanol. Exposure to 3×10^5 rads produces a weight increase of ~11%. At dose rates greater than 10^5 r/hr the inner grafting rate appears to be controlled by the rate of diffusion of monomer into the fibers. Swelled viscose fibers show the most graft copolymerization; unswelled fibers of viscose, cotton and linen show less graft copolymerization, and the amount decreases as fiber density, crystallinity and orientation increase (*8*).

Diffusion rates have important theoretical implications. There is, for example, the difference between the diffusion rate for single pairs of free radicals produced by ultraviolet light in gases and that of multiple pairs produced in liquid systems by radiolysis. This provides a basis for discovering

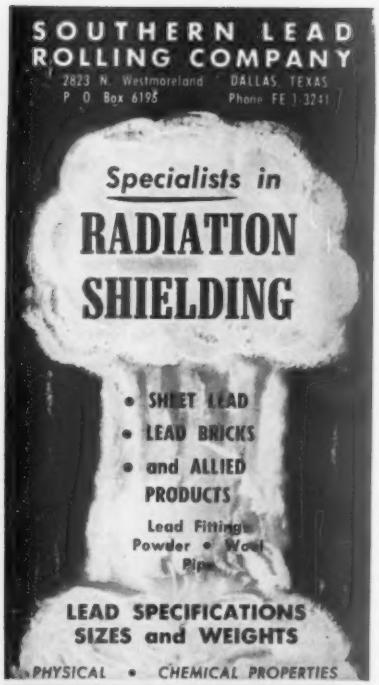
VITREOSIL®
PURE
FUSED
QUARTZ

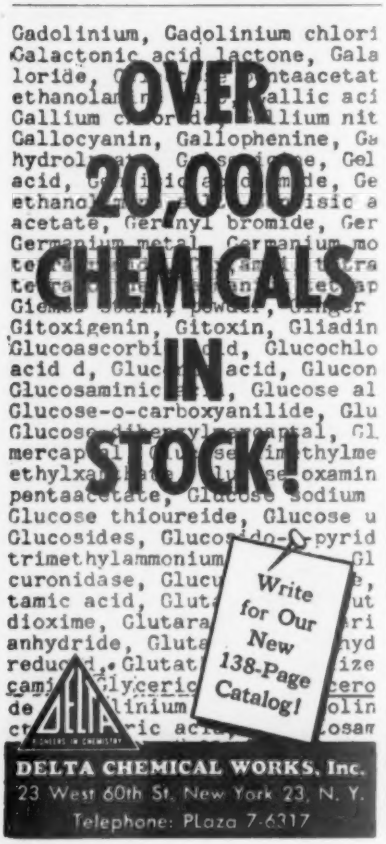


IDEAL FOR
SEMI-CONDUCTOR METALS
Our unique process enables us to supply semi-conductor quality VITREOSIL to close tolerances in crucibles and special fabricated shapes. Write us about your requirements. See our ad in **Chemical Engineering Catalog.**

SPECTROSIL®
FOR HYPER-PURITY IN
SEMI-CONDUCTOR WORK
PURITY—purest form of fused silica
TRANSPARENCY—unique optical properties
HOMOGENEITY—completely homogeneous and free from granularity
AVAILABILITY—block material for lenses, prisms, etc; rod, fiber, wool; hollow ware as tubing, crucibles, and special apparatus.
Write for complete, illustrated catalog.

THERMAL AMERICAN
FUSED QUARTZ CO., INC.
18-20 Salem St., Dover, N. J.


SOUTHERN LEAD ROLLING COMPANY
2823 N. Westmoreland DALLAS, TEXAS
P. O. Box 6195 Phone FE 1-3241
Specialists in
RADIATION SHIELDING
• SHEET LEAD
• LEAD BRICKS
• and ALLIED PRODUCTS
Lead Fittings
Powder • Wool
Pig
LEAD SPECIFICATIONS SIZES and WEIGHTS
PHYSICAL • CHEMICAL PROPERTIES
Call or Write us for figures on your specific requirements in the NUCLEAR FIELD. We can serve you nationally or internationally.


OVER 20,000 CHEMICALS IN STOCK!
Write for Our New 138-Page Catalog!
DELTA CHEMICAL WORKS, Inc.
23 West 60th St. New York 23, N. Y.
Telephone: PLaza 7-6317

This article starts on page 105

special radical reactions in irradiated condensed systems (*6*).

Adding Surface Area

Radiation yields sometimes increase if one adds large-surface-area materials such as finely divided powders or fibers. Sometimes the nature of the products changes. No one really knows why, but some think that a transfer of energy from the surface to an adsorbed reactant is the cause. There may be a catalytic effect.

For example, nitrogen-fixation can be carried out with fission fragments from a large-surface-area microporous uranium fuel. An increased yield of nitric acid results (*9*). Adding zinc oxide, finely divided silica or small glass beads as filler increases the *G*-value for polymerization of isobutene by ten (*10*).

The extent to which adsorbed material covers the solid surface also affects yield. Thus when small amounts of pentane are adsorbed on silica gel, there are higher yields of the branched hydrocarbons isopentane and isobutane from radiolysis of pentane than with larger amounts. If amounts of pentane as great as 5–13% are adsorbed on silica gel, radiolysis produces no branched polymers at all (*11*). Adding silica flour to silicone rubbers increases the effectiveness of radiation vulcanization (*12*).

Sensitizers and Promoters

Chemical additives often increase radiation yields. Graft copolymerization of methylmethacrylate onto polyethylene is nearly four times as great with the addition of 0.01 mole/liter of benzoyle peroxide dimethylaniline (*13*). Without radiation the chemical produces only a small amount of grafting. Addition of propanol-2, octanol-1 or ethyl acetate approximately doubles the grafting of styrene onto polyethylene. The additives apparently reduce the radiation protection of the stable styrene molecule.

Water promotes graft copolymerization of methylmethacrylate and styrene onto polyvinyl-alcohol films (*14*). The effect appears to depend on swelling of PVA to allow monomers to enter. Methylmethacrylate can be grafted onto PVA to the extent of 40 times the weight of the original film with a dose of 5×10^5 r; 10^7 r grafts as much as ten times the film weight of styrene. There must be an amount of water equal to 5–20% of the film.

Carbon tetrachloride, known to be an oxidation accelerator in other systems, increases the rate of radiolytic oxidation of liquid cyclohexane and diisobutylene (*15*). The *G*-value for cyclohexane increases from 0.025 to 2.2.

Crosslinking of PVC. The very high doses required produce so much degradation that radiation crosslinking of polyvinylchloride is normally unprofitable. The *G*-value can be increased from 0.7 to 6.4, however, by adding diallyl sebacate to the PVC (*16*). An even greater increase occurs with triallyl cyanurate. In this interesting system the double bonds of diallyl or triallyl esters lead to greatly crosslinked, rigid products through a free-radical mechanism. Apparently the radiation produces an allylic radical. This is not in itself capable of addition to the relatively unreactive allyl monomer, but it can abstract an atom from the PVC to create a vinyl-polymer free radical that is active enough to add to the allyl monomer. With irradiations of 8–25 megarads and increasing proportions of triallyl cyanurate, products show progressive improvement in tensile strength at 150° C up to a strength of 1,000 psi. Solvent resistance also improves.

Some carbonyl-containing chemicals, for example benzephenone, are effective sensitizers for crosslinking of polyethylene and other polymers by ultraviolet light (*17*). The sensitizer absorbs the light and is decomposed. The free radicals produced abstract hydrogen from the polymer and induce crosslinking.

An exciting challenge to future research is the influence of trace amounts of materials in irradiated systems. In some situations trace additives function as quenchers. Studies of luminescent decay of cyclohexane suggest that trace additives interact with excited cyclohexane molecules in times as short as 10^{-9}–10^{-10} sec (*6*). In other situations trace additives function as sensitizers; small amounts of cobaltous ions (Co^{++}) in zeolite solids increase by many fold the yield of hydrogen from radiolysis of pentane adsorbed on the zeolite (*11*). No explanation has been established for these effects. In the pentane-on-zeolite case a charge-transfer phenomenon may be involved.

Small Dose Rates

A combination of intermittently applied radiation and low dose rates pro-

duces exceptionally large yields of graft copolymer and a minimum of homopolymer. Small dose rates are more efficient than large ones because polymerization depends on intensity to a power smaller than one. Intermittent application allows time for diffusion of monomer to the polymer grafting sites; the process becomes more efficient. In this way methylmethacrylate can be copolymerized onto polyethylene film until the original film weight is multiplied by 64 (*16*). To do it a total dose of 31,400 r was delivered at an instantaneous dose rate of 31,400 r/hr and a duty cycle of 2 min on, 28 min off for 15 hr. Homopolymer content was only ~3%. Instantaneous grafting rate appeared to be autoaccelerated by production of active grafting sites on both the original polyethylene backbone and newly grafted methylmethacrylate side chains.

Radiation Synthesis

Laboratory preparation of certain dichlorophosphines and nitroso compounds is more convenient by radiation synthesis than by conventional methods (*18*). The big advantages are (a) one-step processes and (b) simple starting materials.

Particularly productive are combination reactions, in which free radicals from different components of a mixture combine to form the product. In this manner dichlorophosphines have been directly synthesized from phosphorus trichloride and aliphatic, olefinic and aromatic hydrocarbons.

Scavenger reactions also have good yields. For example, you can continuously add the radical scavenger nitric oxide to maintain a low concentration in irradiated organic liquids (*18*). The process forms trichloronitrosomethane from CCl_4-NO mixtures and dichloronitrosomethane, not previously synthesized, from $CHCl_3$-NO mixtures.

Other radiation synthesized compounds include dichlorocyclohexyl phosphine, 3-cyclohexenyl phosphorus dichloride, dichorocyclohexylarsine, organic silicon trichlorides and trichloromethylcyclohexane. These compounds come from the formation by radiation of carbon bonds with silicon, chlorine, phosphorus, nitrogen and arsenic (*18*).

Emulsion Polymerization

A direct method for forming a stable cationic emulsion of polyvinyl acetate is radiation polymerization of the monomer in an aqueous solution containing a cationic detergent (*19*). Radiation appears to initiate the polymerization both by direct action on the monomer and by creation of radicals in the water that react with the monomer.

Irradiation of mixtures of different emulsified polymer lattices with vinyl monomers has been shown to be a useful method of preparing nonrandom graft copolymers (*20*). Relatively small doses are required, and product purification is achieved by fractional precipitation.

Other significant revelations at Warsaw were these: commercial production of graft-copolymer-coated Teflon that is bondable and dyeable (*21*), improvement of Nylon dyeability without loss of tensile strength by vacuum preirradiation (*22*), commercial availability of radiation crosslinked plastics with built-in memory (on heating they return to the shape in which they were irradiated) (*23*), the possibility of irradiating plastics before molding and heating to complete the cure (*23*), existence of a fission-product pilot plant in Romania for studying partial oxidation of paraffin hydrocarbons (*24*), radiation vulcanization of a better silicone rubber by a method simpler than peroxide curing (*25*), economic sterilization of ampoules of water for medicine (*26*), and radiation synthesis of colorants (*27*).

* * *

The author acknowledges the able assistance of his associates, E. I. Heiba and R. P. Epple of Arthur D. Little, Inc., in reviewing the content of papers.

BIBLIOGRAPHY

All of the following references are papers presented at the Warsaw Conference on Applications of Large Radiation Sources, September 8–12, 1959. The authors' countries are indicated in parentheses, and the paper is identified by the number assigned to it at the conference.

1. J. I. Thomas (UK) CW/IIB/86
2. Borelko, Kartoshova et al. (USSR) (unlisted)
3. A. V. Topchiev (USSR) CW/11c/84
4. N. P. Sirkus, A. Ch. Breger, B. E. Vanshten (USSR) CW/I/81
5. S. S. Medvedev, A. D. Abkin, P. M. Chomikovski (USSR) CW/IIB/82
6. M. Burton (US) CW/S/66
7. M. Durup et al (France) CW/IIC/45
8. S. Okamura et al (Japan) CW/IIB/36
9. R. Coekelbergs et al (Belgium) CW/Ip2/13
10. A. Charlesby (UK) (unlisted)
11. J. W. Sutherland, A. O. Allen (US) CW/IIC/14
12. (unlisted) (USSR) CW/IIC/85
13. J. Dobo et al (Hungary) CW/IIB/3
14. I. Sakurada et al (Japan) CW/IIB/39
15. R. Montarnal (France) CW/IIC/25
16. S. H. Pinner (UK) CW/IIA/8
17. G. Oster (US) CW/IIA/72
18. A. Henglein (Germany) CW/IIC/50
19. S. Okamura et al (Japan) CW/IIB/34
20. P. Hayden, R. Roberts (UK) CW/IIB/18
21. P. C. Aebersold (US) CW/S/57
22. S. Matsumura *et al.* (Japan) CW/IVA/62
23. A. Charlesby (UK) (unlisted)
24. G. Joanid *et al.* (Romania) CW/IIC/43d
25. (unlisted) (USSR) CW/IIC/85
26. Paul Adrian *et al.* (Romania) CW/IVB/44d
27. F. Balestic, M. Magat (France) CW/IIC/42

E.M.I. Portable Contamination Monitor Type 1

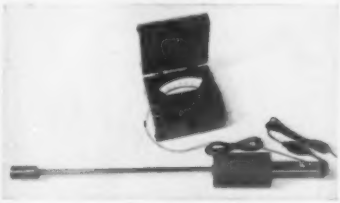
For efficiency, sensitivity and convenience, the scintillation counter, using a photomultiplier in one of its many current E.M.I. forms, is undoubtedly the most universally useful device for the detection and measurement of alpha, beta and/or gamma rays.

The range of E.M.I. photomultiplier tubes is probably the largest in the world. As well as an extensive list of standard types effectively covering all the principal photoelectronic applications, special tubes can be produced to suit specific problems. Send us your inquiries—our design team will gladly co-operate with you.

EMI

E.M.I. ELECTRONICS LIMITED
VALVE DIVISION
HAYES · MIDDLESEX · ENGLAND EE.84

New higher sensitivity
GAUSSMETERS



Rawson-Lush patented Rotating Coil type, now available with a wide range of coil sizes to give different sensitivities. New large coil type 726 indicates the Earth's magnetic field.

FEATURES—Type 726:

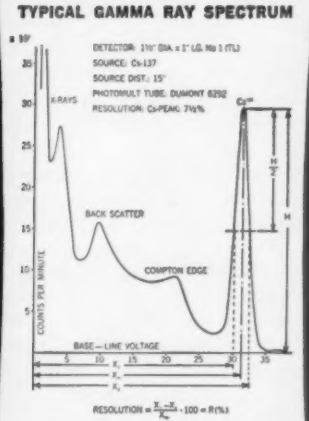
- Ranges 3 — 10 — 30 — 100 — 300 — 1000 gausses full scale, all in one instrument. Tip diameter 1½".
- Guaranteed accuracy 1% or better. Readings are obtained on a high-quality laboratory type meter with a five inch scale length, knife edge pointer, mirror scale.
- Does not require field uniformity. Coil gives average field over its volume, so a distorted field can be measured.
- Measures component of the field in a desired direction, as well as total intensity.
- Simple operating principles, simple to use and maintain.
- Compact and portable, just one meter and long probe unit.

Also available—type 504 Fluxmeter, for measuring lines in magnetic circuits. Send for bulletins.

RAWSON ELECTRICAL INSTRUMENT COMPANY
fine instruments since 1918
114 Potter Street Cambridge, Mass.

Sodium Iodide (Tl) Crystals
now available with a GUARANTEED RESOLUTION

TYPICAL GAMMA RAY SPECTRUM



Scintex Brand Crystals are unconditionally guaranteed for one year under normal usage.

CRYSTALS DIVISION
ISOTOPES, INC.
123 Woodland Avenue, Westwood, New Jersey

BOOKS

Uranium Production Technology

Edited by C. D. HARRINGTON and A. E. RUEHLE (D. Van Nostrand Co., New York, xii + 577 pages, $17.50)

Reviewed by JAMES F. SCHUMAR, Argonne National Laboratory, Lemont, Ill.

The editors of "Uranium Production Technology" have made an excellent contribution to the technology of the expanding nuclear power industry. The production of high-purity uranium metal and compounds of the quality required for nuclear reactors and the isotopic separations plants of the AEC was indeed a tremendous task. The efforts of many teams of scientists and engineers from the start of the Manhattan Project to the present-day government and commercial plants are very well summarized in this book.

A large section of the book is devoted to the technology of the purification process, the production of UO_2, uranium tetrafluoride and uranium metal.

The first commercial process for producing pure uranium was a batch process using diethyl ether as the extract. This process was followed by a continual dual-cycle ether-extraction process. Both processes are well described, and flow diagrams, equipment, operating conditions and costs are included.

Tributyl phosphate was selected as a solvent for uranium purification in two of the large AEC plants because of safety and lower capital and operating costs. The entire process at the National Lead Company of Ohio and Mallinckrodt Chemical Works is described in detail. Again, flow diagrams, description of equipment and step by step procedures are discussed.

The technology for producing UO_3 both by a batch process and by a continuous process is fully described. Two major steps are involved in the production of UO_3: (1) concentrating the uranyl nitrate solution by evaporation to uranyl nitrate hexahydrate and (2) heating the uranyl nitrate hexahydrate further so that dehydration and denitration yield the UO_3 product.

UO_3 is produced by contacting the UO_3 with hydrogen gas in such a way that the products of reaction are UO_2 solids and water.

Both continuous and batch processes for producing UF_4 from UO_2 are described. The production of uranium metal by thermite reduction of UF_4 with magnesium or calcium and casting, as well as the production of uranium dingot metal by direct thermite reduction of the UF_4, are outlined in detail including equipment used, procedures and costs.

An excellent chapter on physical metallurgy discusses the aspects of the physical metallurgy of uranium that relate directly to problems of metal production and fabrication. Included in this chapter are the metallurgy of impurities, defects, grain structure and heat treatment of pure uranium. A description is also given of the uranium binary-alloy systems.

Fabricating techniques to produce various geometries of uranium metal are also discussed in detail. These involve press forging, extrusion, rolling, heat treatment and machining. The fabrication procedures used for making slugs for the Hanford reactors and a description of the uranium metal slug quality are included in the chapter on uranium metal fabrication.

The text is concluded with a short chapter devoted to the recent changes in the technology of uranium. The last chapter is devoted to the health hazard problem, its control and general engineering approach.

Nuclear Technology for Engineers

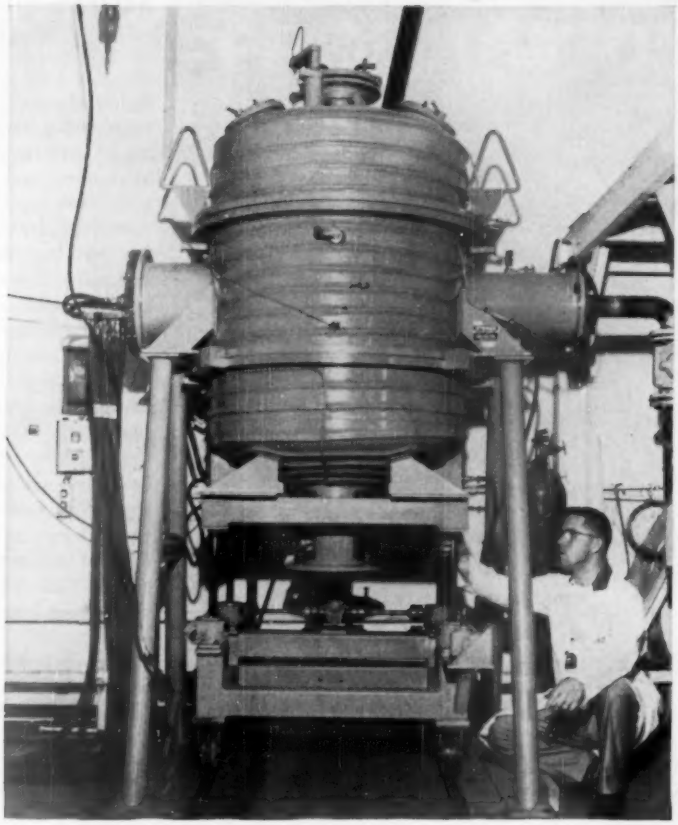
By R. HOBART ELLIS, Jr. (McGraw-Hill Book Co., New York, 1959, x + 284 pages, $9.50)

Reviewed by V. L. PARSEGIAN, Rensselaer Polytechnic Institute, Troy, N. Y.

The author expresses the hope that the reader "will like this book," from conviction that technical books are not often enough written attractively. I think many people who have some technical background will like his comfortable style for introducing nuclear concepts.

The volume begins with electrons, protons, neutrons and a rather simplified "quantum-mechanics" picture of atomic forces and the structure of nuclides. Radioactive decay, properties of emitted radiation, are discussed in some detail, including techniques for detecting radiation. There is a summary of radioactive tracer techniques that are found useful in various fields.

Three chapters discuss isotope and machine sources of radiation, effects and uses of radiation, and dosimetry techniques. The liquid-drop model introduces nuclear fission and a brief



Installed at Atomics International, Canoga Park, California, Stokes 50KW vacuum furnace is accomplishing diverse and unusual melting and casting tasks.

Photograph courtesy of Atomics International, a division of North American Aviation, Inc.

How a Stokes vacuum furnace handles tough nuclear assignments . . .

There's practically no margin for error in melting and casting uranium for reactor fuel. For the exceptional precision and unusual versatility of equipment demanded in this application, Atomics International, a division of North American Aviation, Inc., installed a Stokes 50KW vacuum casting furnace.

The Stokes furnace has handled some notably tough assignments at Atomics International. For example, it cast long, hollow uranium cylinders to such size tolerances that no subsequent machining was required. For another project, the furnace was operated remotely in the casting of uranium fuel slugs. In both applications, maximum precision had to be sustained through tight, large-scale production schedules. The achievement of melting assignments such as these demand nothing short of the utmost in equipment and process efficiency.

Take advantage of Stokes advanced vacuum technology. The Stokes Engineering Advisory Service will help you plan the installation that best meets your individual requirements.

Vacuum Metallurgical Equipment Division
F. J. STOKES CORPORATION
5500 Tabor Road, Philadelphia 20, Pa.

STOKES

TO A
PHYSICIST'S
PHYSICIST

In your hands lays the promise for future developments in industrial nuclear energy. To this end, the Atomic Power Department of Westinghouse is devoted. Your assignment will be concerned with the complex problem of new reactor concept and development. You will have the opportunity to travel and meet with scientists from other countries who are engaged in similar work. At Westinghouse you will have the stimulating association with the foremost scientists in the field of industrial nuclear technology and you will know that your contributions have gained the recognition they deserve.

Working at the Atomic Power Department will enable you to take advantage of what has been called the Renaissance City of America—Pittsburgh. Here, the evidence of the atomic age is strikingly present by the number of world-renowned research centers devoted to nuclear science. In addition to all of this, you have the advantages of gracious suburban living.

SENIOR SCIENTIST . . . PhD physicist or mathematician with an unusual degree of alertness and initiative. MS in physics or mathematics with several years experience in either reactor calculations or critical experimentation.

SCIENTIST . . . PhD in physics with experience in the Atomic Field desirable, but not essential; or BS degree with 5 years experience in the nuclear field ORSORT or nuclear engineering background acceptable.

SCIENTIST . . . PhD in physics or related fields. Must have the type of personality that lends itself to LRMD work and in addition possess a high degree of creative ability.

Send resumé to Mr. C. S. Southard,
Westinghouse Atomic Power Dept., P. O. Box 355, Dept. W-73, Pittsburgh 30, Pa.

Westinghouse
FIRST IN ATOMIC POWER

BOOKS

Department starts on page 108

review of conditions that permit chain reaction in a nuclear reactor; a succeeding chapter describes typical reactor assemblies and problems connected with their operation and economics. A final chapter introduces the principles for deriving energy from fusion of atoms and briefly describes several approaches to electromagnetic containment of plasmas.

Books that attempt to make nuclear physics easy and comfortable are particularly vulnerable to attack from physicists; it is very easy to feel irritation with oversimplified pictures of quantum mechanics and atomic structure. On the other hand, avoiding these subjects altogether except in difficult detail is an even greater sin against those who are not physicists.

The book is not intended for chemists or physicists. But industrial firms that have interest in atomic energy could properly place this on the shelves of patent attorneys, managers and others who need some acquaintance with the subject. It can be useful for introductory study at college level for those who do not intend to delve more deeply into atomic and nuclear physics. However, it seems to have been particularly intended for engineers who need "nonacademic" introduction before going to more special interests in nuclear energy.

[EDITOR'S NOTE: Alert readers of NUCLEONICS will recall that the author of the above-described book is an Associate Editor of this magazine.]

Geneva '58 Proceedings

Other volumes have been described beginning with the July NUCLEONICS.

Vol. 6, Basic Metallurgy and Fabrication of Fuels (720 pages, $18), includes Sessions E-13 (Basic Studies in Metallurgy and Ceramics), and E-17 and E-18 (Fabrication of Fuels, Parts I and II). The first part reports on the properties of uranium, thorium and plutonium and their alloys and oxides —physical properties, phase relationships, and corrosion and irradiation effects. The fabrication sessions describe the fabrication and design of the fuels for various specific reactors, the technology of some of the newer fuels and fabrication techniques.

Vol. 15, Physics in Nuclear Energy (476 pages, $12.50) records the papers

and discussion of Sessions A-21 and A-22 (Basic Physics in Nuclear Energy, Parts 2 and 3). Here are both experimental and theoretical papers on such basic questions as fast-neutron cross sections, neutron capture and nuclear levels, nonneutronic fission, the fission process and fission fragments.

Vol. 18, Waste Treatment and Environmental Aspects of Atomic Energy (624 pages, $16.50), contains the records of Sessions C-21 and C-22 (The Treatment of Radioactive Wastes, Parts 1 and 2) and Session D-19 (Environmental Aspects of the Large Scale Use of Atomic Energy). The first session covers high-level-waste handling experience and research, reflecting the present emphasis on solids suitable for ultimate disposal. Session C-22, on low-level-waste treatment, includes papers on liquid and gas purification and recovery of uranium and individual radioisotopes from wastes. The last session is concerned with environmental effects of the nuclear industry.

Vol. 22, Biological Effects of Radiation (552 pages, $14.50), provides, in the papers of Sessions D-9 and D-10, a broad review of the present knowledge of the effects of radiation on biological systems—radioresistance, effects on organs and systems, effects on the nervous system, genetic effects, radiation-effects mechanisms, carcinogenic effects and symptoms of radiation injury. It is evident that we still lack a real understanding of these effects.

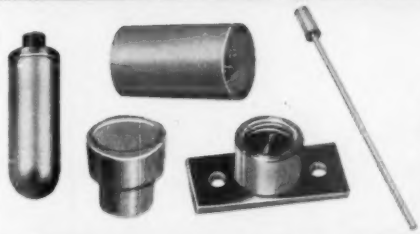
Vol. 26, Isotopes in Medicine (460 pages, $13), is concerned with diagnostic and therapeutic applications, which are the respective subjects of Sessions D-17 and D-18. The number of papers concerned with thyroid studies reflects the large proportion of diagnostic work directed to the thyroid relative to other specific areas, such as the circulatory and nervous systems. Therapeutic papers are in the areas of teletherapy, interstitial and intracavitary therapy, and metabolic localization.

Vol. 32, Controlled Fusion Devices (463 pages, $15). Here in one volume are paraded the fusion experiments of all the countries of the world as presented at Geneva. Tuck's masterful review of controlled thermonuclear research at Los Alamos heads a list that includes contributions from Britain's Thompson, Russia's Golovin, Sweden's Siegbahn, etc. Needless to say, all the U. S. groups are represented.

PRODUCT DIGEST from U. S. RADIUM

ISOLITE LIGHT SOURCES

New 360° light source and high-brightness one-way lamps use luminescent bulbs energized by Kr^{85} gas. Units visible at 500-2000 ft., depending on model, size, color; service life to 10 years. New Isolite markers, signs and placards now available. **Request Bulletin 30.32F2**



RADIATION SOURCES

Sealed beta, gamma and neutron sources for research, gauging, radiography and related applications are available with varying intensities and energies. **Request Bulletins** 20.20FB2, 20.30FG2, 20.40FN2

RADIATION SOURCES FOR ELECTRON TUBE IONIZATION

Specially-fabricated isotope sources—Ni^{63} plated electrodes and radium foil—are now being produced as ionization sources for electron tubes.

CATHODE-RAY TUBE PHOSPHORS

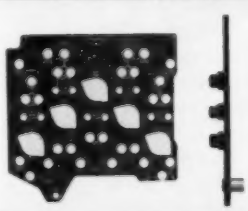
USR offers a variety of phosphors for TV and industrial cathode-ray tube applications. **Request** CRT Notes

DIALS, PANELS AND NAMEPLATES

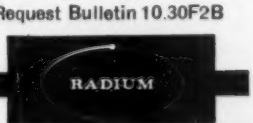
Metal dials and panels include a greater variety of finishes, colors and processes than ever before. **Request Bulletin 10.30F2A**

New lithographed nameplates and panels featuring special hard, abrasion-resistant finish are available with or without adhesive backing in various thicknesses.

EDGE-LIGHTED PANELS

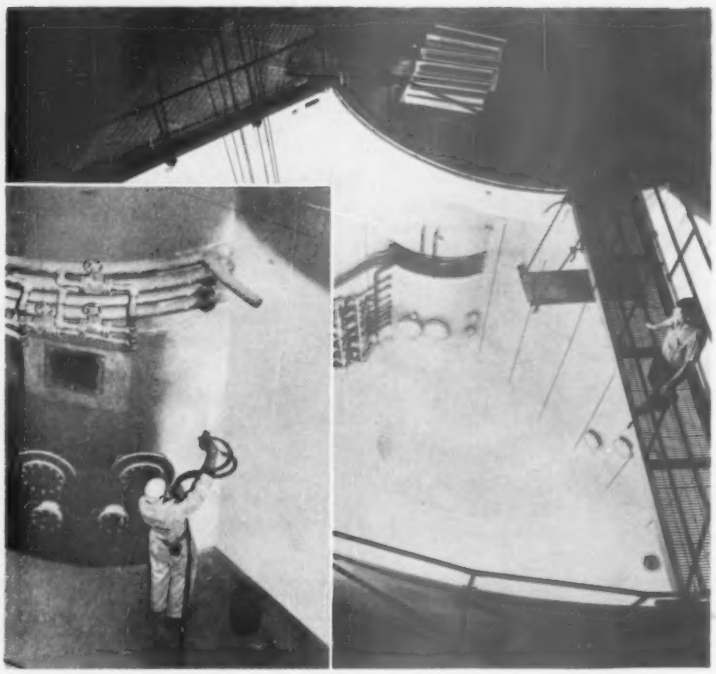


Special-purpose panels and dials accurate to MIL spec are available from United States Radium Corporation. Standard edge-lighted and integral edge-lighted products by Lackon® provide optimum legibility and contrast, with high resistance to humidity, surface abrasion. **Request Bulletin 10.30F2B**



UNITED STATES RADIUM CORPORATION

MORRISTOWN, N. J. | Offices: Chicago, Illinois and North Hollywood, Calif. Subsidiaries: Radelin Ltd., Port Credit, Ont., Canada and U. S. Radium Corp. (Europe), Geneva, Switzerland.



Radiation Resistant Epoxy Coating

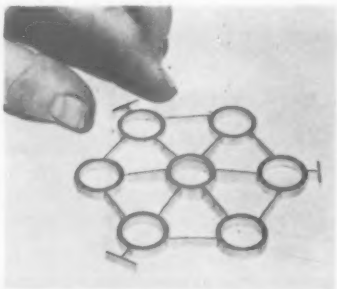
Special epoxy coating has been developed for coating concrete and steel that will be exposed to large doses of gamma radiation. First application is NASA's 60-Mw Plum Brook testing reactor (above). Test samples have received 1×10^9 rad dose and exposure to boiling distilled water for 9,500 hr without flaking, blistering or cracking. The Epon resin system consists of a two-part cold curing vehicle that utilizes amine curing agent to harden the resin. Same basic epoxy resin is employed for red primer coat, gray mastic coat (which is imbedded with glass cloth) and white finish coat. Coating thickness is 23 mils on concrete, 16 mils on steel.—Shell Chemical Corp., 50 W. 50th St., New York 20, N. Y.

High-Density Metal

Mallory 3000 has density of 17.00 gm/cm³ and Rockwell C hardness of 24, and can be cold-worked and formed into a wider range of shapes than other high density metals. Rolled sheet available in sizes up to ¼-in. thick, 8-in. wide and 40-in. long.—Mallory Metallurgical Co., Indianapolis 6, Ind.

All-Inconel Evaporator

An evaporator made entirely of Inconel will have an entrainment section of woven stainless-steel 6 times usual thickness. Wash-down and purge water from entire Indian Point reactor will be vaporized by the system with <5 parts in 100,000,000 dissolved solids remaining in discharge.—Chicago Bridge & Iron Co., 332 So. Michigan Ave., Chicago 11, Ill.

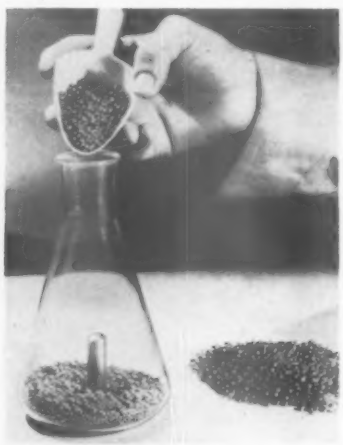


Brazing Alloy for Stainless

Stainless-steel fuel-cluster-rod separators (above) are made by brazing 25 different pieces. The 25 type-302 stainless-steel pieces were brazed in a H_2 furnace at 2150° F using Nicrobraz brazing alloy (a Ni-base stainless-type material).—Wall Colmonoy Corp., 19345 John R. St., Detroit 3, Mich.

High Strength Ni-Alloy Steels

Yield strengths exceeding 250,000 psi have been achieved with 25% nickel-alloy steels. Elongation of 6–10% and area reduction above 20% are obtainable in section thicknesses. High-strength properties are obtained without liquid quenching. Materials are weldable in hardened condition without preheating, are readily hot-worked and can be produced in all commercial shapes.—The International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.



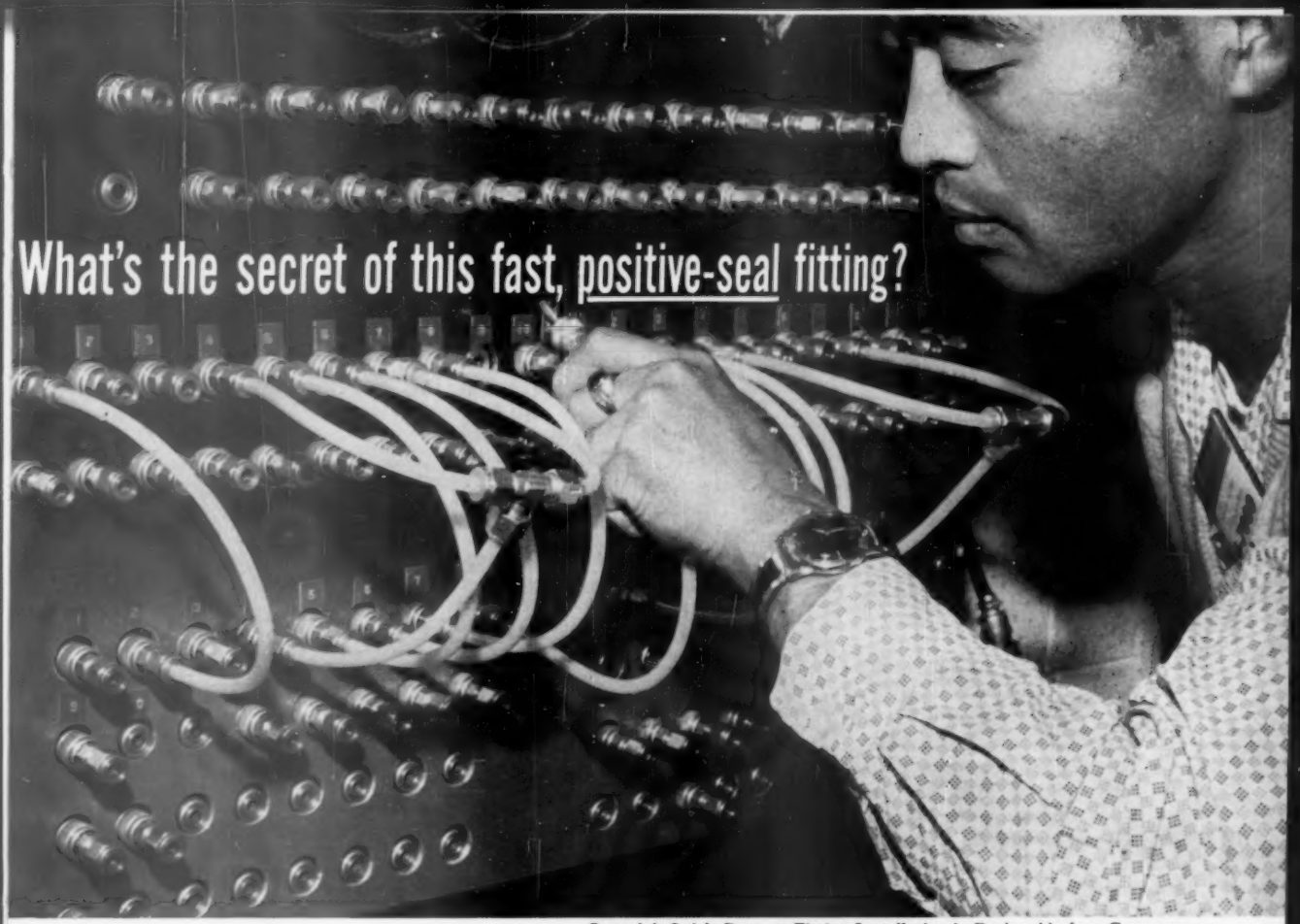
Amorphous Shielding

Homogeneous alloy of W, Ni and Cu fabricated by powder-metallurgy techniques into spheres from 1/16- to ¼-in. dia forms a flexible shielding material (above). Metal shield can be poured like sand or pumped in viscous solution to fill variously shaped volumes. Density of spheres, which can be used in temperatures up to 750° F, is 16.7–17.0 gm/cm³.—P. R. Mallory & Co., Inc., 3029 E. Washington St., Indianapolis 6, Ind.

Pd Leaks; Occluded-D_2 Targets

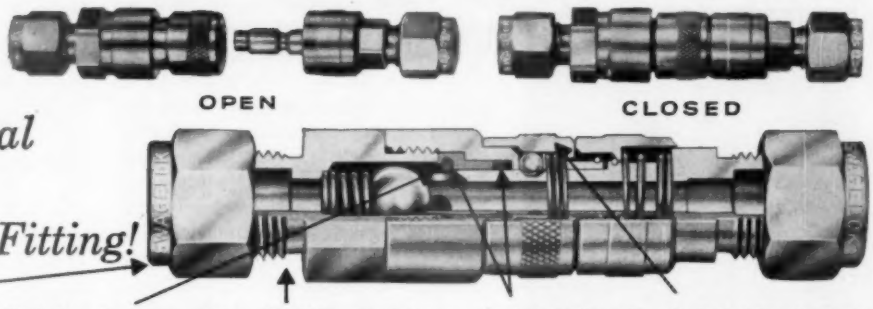
Leak valve for control of H_2 and D_2 flows has palladium thimble, 3½-in. dia chamber and is 4½ in. high. Input and output connectors are female ⅛-in. dia pipe fittings; input can be pressurized up to 15 psi. Valve is heated by external 117-v heater.

Thin deuterium-occluded-in-titanium accelerator targets are available



Swagelok Quick-Connect Fitting Installation in Boeing Airplane Company, Seattle, Wash., Test Facilities for Boeing 707 Jet Stratoliner.

Here's the secret of this fast, positive-seal Swagelok Quick-Connect Fitting!



1. Swagelok Quick-Connects with single end or double end shut off for tube to pipe, tube to tube, bulkhead tube to tube applications are available in brass and stainless steel in sizes for ⅛" and ⅜" O. D. tubing.

2. Flow resumed instantly and vacuum tight seal assured when connection is made.

3. Light, compact, streamlined design. Occupies little space. For use with portable equipment, and bulkhead or panel applications.

4. Instant-acting seals completely prevent loss of pressure when fitting is disconnected.

5. No twisting, turning or wrench action necessary. Easy straight-line finger tip pull or push action for instant connecting or disconnecting.

In the Boeing Airplane Company photo shown above, the tubes are instrumentation pressure lines running from the large jet engines on test stands to the patch board, where the lines are coupled into measuring devices.

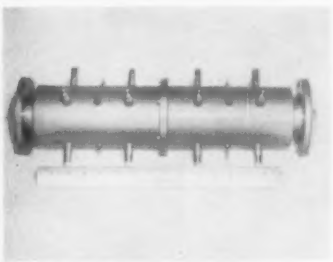
The Boeing Airplane Company adopted this positive Swagelok Quick-Connect Fitting to simplify test installations, and substantially cut down test set-up time. Both ends of the many pressure lines are Swagelok-equipped. Previously, engineers used a screw-type fitting which required a wrench and valuable time-consuming operations to tighten and remove.

Swagelok engineers are equipped with experience, ability, and a wide range of tube fittings designed to meet your individual problems. Quick delivery of Swagelok tube fittings from local distributor stocks.

Swagelok® TUBE FITTINGS

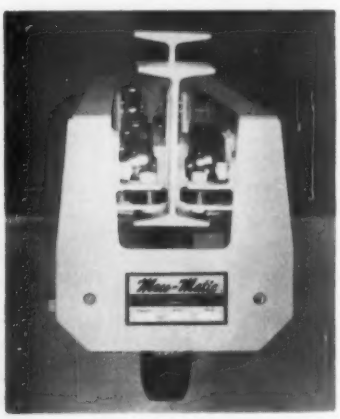
CRAWFORD FITTING COMPANY
884 East 140th Street • Cleveland 10, Ohio
Crawford Fittings (Canada) Ltd., Niagara Falls, Ontario, Canada

on 1.125-in. dia foils with full 1.125-in. dia active area. Mo is backing material for 20-mg evaporated film. Occluded D_2 exceeds 8.0 cm^3 per target. Other sizes are available.—Scientific Engineering Laboratories, Inc., 1510 Sixth St., Berkeley 10, Calif.



Accelerator Lens

Electrostatic strong-focusing lens (above) can focus an ion beam 15–20 ft from image of analyzing magnet. Unit cancels normal astigmatism produced by focusing action of analyzing magnet. Lens can work far from accelerator without sacrificing beam intensity. Pole piece can be adjusted while system is operating. Lens flanges are adjustable to purchaser's system.—Texas Nuclear Corp., P. O. Box 9267, Austin, Texas.



Versatile Crane

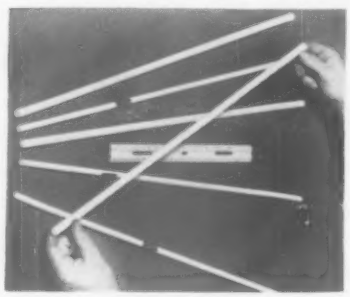
Overhead crane (above) is operable on over 40 standard structural I-beam sizes, wide-flange beams and on hardened monorail track. Free-floating flangeless wheels and side guide rollers bear against web of beam enabling crane to transverse junction of unlike beams. Motor-driven, handgeared and push-type units are available.—Mechanical Equipment Co., Inc., Dept. 155, 3100 Prospect Ave., Cleveland 15, Ohio.

Nb, Ta and V Tubing

Columbium (niobium), tantalum and vanadium are available in small-tubing form. Tubing is furnished in seamless grade and in fully annealed, half-hard-drawn and full hard and intermediate tempers. Sizes are from 0.012 to 1.125 in. o.d.—Superior Tube Co., 1552 Germantown Ave., Norristown, Pa.

Nuclear Quality Tubing

Nuclear quality heat exchanger and fuel element tubing have been developed in stainless steel types 304, 304L, 316, 347 and 348. Maximum limits are set for C, Mn, P, S and Si (plus for Ta in 348). For fuel element tubing, maximum Cu, Mo, Co and B is specified.—Superior Tube Co., 1552 Germantown Ave., Norristown, Pa.



BeO Ceramic Tubing

BeO ceramic tubing (above) that is highly resistant to elevated temperatures and thermal shock is available in lengths to 24 in. Tubing can have both ends open or one end closed for insulation and protection of sensing and/or measuring elements. High-fired surface is permanently dust-free; high density of material renders tubing essentially gas-tight.—National Beryllia Corp., 4501 Dell Ave., No. Bergen, N. J.

Welded Stainless-Steel Tubing

Welded 304 stainless-steel tubing manufactured to very close tolerances is used for the Fermi Reactor fuel-core subassemblies (above). The square tubes have 0.093-in.-thick walls and square cross section of 2.646 ± 0.0035 in.—The Standard Tube Co., 2440 Plymouth Rd., Detroit 39, Mich.

Zircaloy-2 Tubing

Zircaloy-2 tubing has been extruded in record 51½-ft lengths with 0.36 in. wall and 3.58-in. o.d. on 8,000-ton press.—Harvey Aluminum, 19200 S. Western Ave., Torrance, Calif.

Hot Air Butterfly Valve

A 10-in.-dia butterfly valve (above) can withstand temperatures to 1,200° F and pressures to 350 psi. Inlet connection is flanged and outlet is secured by clamp-type fastening. Sealing damper is No. 25 Stellite; body bore at sealing ring is flame-plated tungsten carbide.—Parker Aircraft Co., 5827 W. Century Blvd., Los Angeles 45, Calif.

Stainless-Steel Rotary Pump

Slow speed, heavy duty and longer pump life are features of a 316 stainless-steel positive-displacement rotary pump. Helical timing gears, twin balanced impellers and single or dual

LOW IN COST . . . PORTABLE, TOO!

NEUTRON OUTPUTS UP TO 10^{10} NEUTRONS/SEC

FOR USE IN:

- All types neutron diffusion studies on fast, intermediate and slow, critical studies.
- Activation Analysis
- Neutron Scattering and Nuclear Reaction Research
- Radiation Damage Studies
- Biological Studies
- Training of Nuclear Scientists
- Instrument Calibration
- Well Logging Research
- Models completely installed with targets begin at $19,950. FOB Austin. (Larger units also available)

A unit so compact it can be moved easily from one laboratory to another if desired.

FACTS AND FIGURES

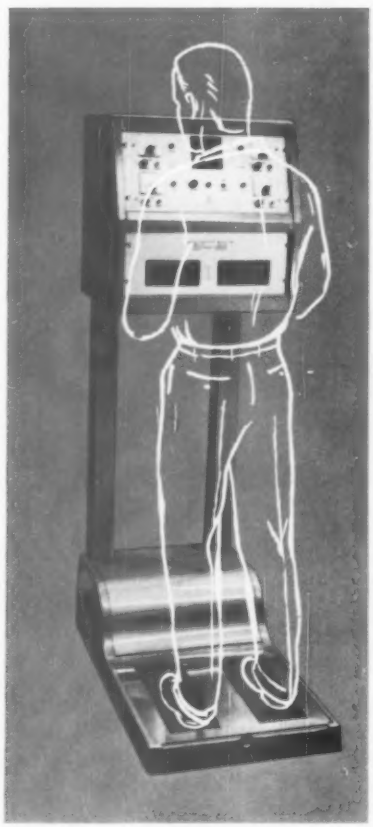
Output up to 10^{10} neutrons/sec continuous: remote operation; mobile; no special building facilities needed. Easily operated and maintained; Beam Pulsing system available.

For further information, write:

DEPARTMENT AA

TEXAS NUCLEAR CORPORATION

P. O. Box 9267 Austin 17, Texas



HAND AND FOOT MONITORS FOR ALPHA AND BETA-GAMMA CONTAMINATION

To fulfill the requirements of the health industry for economical and reliable instruments in personnel monitoring, Eberline Instrument Co. presents Hand and Foot Monitors for detection of both Alpha and Beta-Gamma contamination.

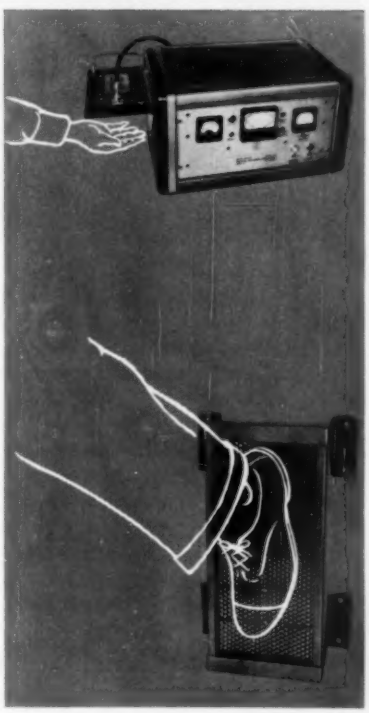
Incorporating the finest in count rate circuitry and utilizing detectors best suited for the application, the amount of radioactivity on the hands and feet is determined and presented on front panel alarm type meters. These first line instruments permit the individual to monitor himself, thus controlling the spread of radioactive contamination.

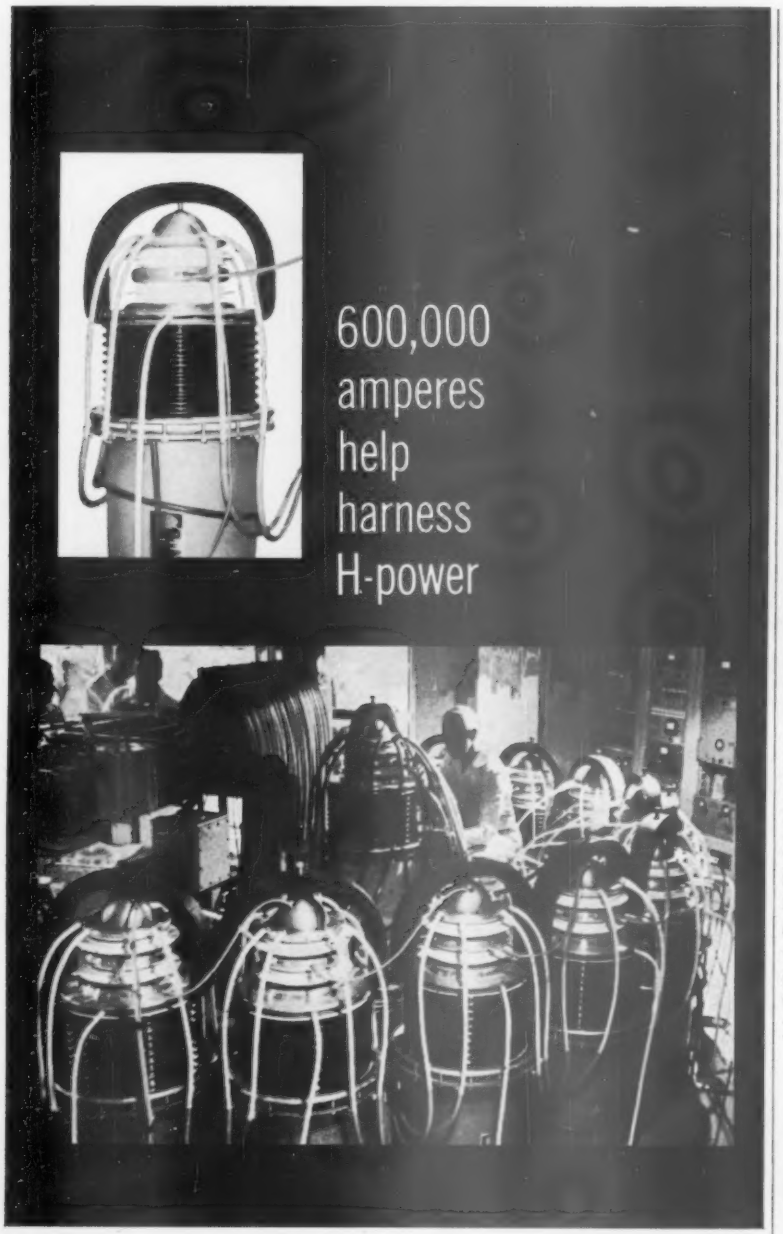
Engineered for long life and minimum down time for maintenance and repair, these fine instruments provide complete and convenient monitoring for personnel required to be in potential contamination areas.

WRITE FOR TECHNICAL INFORMATION

EBERLINE *Instrument Corporation*

P. O. BOX 279 SANTA FE, NEW MEXICO





At the historic Geneva Atoms-For-Peace Conference, Los Alamos scientists unveiled Scylla—a fusion device used to heat a plasma of ionized heavy hydrogen particles millions of degrees by blasting it with a 600,000-ampere thunderbolt.

Surrounding the heart of this thermonuclear machine is a bank of Tobe low-inductance, energy-storage capacitors...each rated at 100,000 volts, each capable of a 20,000 megawatt peak surge.

Why Tobe capacitors? Because only Tobe, with over 30 years of capacitor experience, could meet the rigid design specifications set for the project. Tobe capacitors can meet yours, too. We invite inquiries for a single energy storage capacitor or a complete energy storage system including capacitors, racks, interconnecting lines, protective devices and charging power supply.

For further technical information or engineering aid, write to Cornell-Dubilier Electric Corp., Marketing Office, Norwood, Mass.

CDE **CORNELL-DUBILIER ELECTRIC CORPORATION**
Affiliated with Federal Pacific Electric Company

PRODUCTS & MATERIALS

Department starts on page 112

mechanical seals are utilized in the self-priming pump. Capacities range to 100 gpm against head pressures of 200 psia.—Waukesha Foundry Co., Pump Div., Waukesha, Wisc.

Free-Piston Pump

Using only nine moving parts, three-cylinder free-piston pump (above) can pump anything that flows. Compressed air is introduced into each cylinder in sequence; while left cylinder is discharging, center is filled and waiting and right is filling. Air pressure at 100 psi will maintain 220-ft head of water. Capacities of pumps range from 10 psi to more than 1,000 psi.—The Crossley Machine Co., Trenton, N. J.

Magenta and Yellow Rope

A special magenta and yellow plastic rope (above) is available for marking off radiation areas.—Phillips Petroleum Co., Bartelsville, Okla.

Gamma-Ray Standards

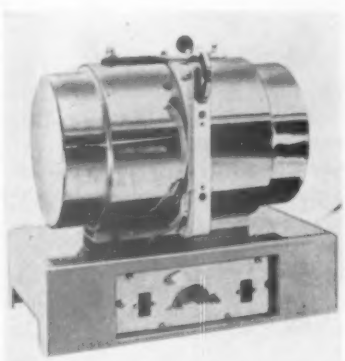
Sr^{85}, Ni^{65} and Hg^{203} γ-ray standards are available in approx 5 gm of solution sealed in glass ampoules for $27.00 each.—National Bureau of Standards, Washington 25, D. C.

Hand, Shoe Monitor

Use of three switches in each of the hand and shoe channels provides up to 15 different scaling factors giving β and γ hand and shoe monitor (above) wide range of operating limits. Incomplete check is indicated by a positive warning. External probe is provided for checking other areas of body.—Technical Associates, 140 W. Providencia Ave., Burbank, Calif.

Insulation Tester

Self-contained, portable insulation tester (above) has max range of 2×10^{13} ohms; test voltages (from transistorized r-f oscillator and step-up transformer range) up to 10 kv. Four resistance ranges start at 200 meg.—Miles Hivolt, Ltd., 13 Mortimer Rd., Hove 3, Sussex, England.



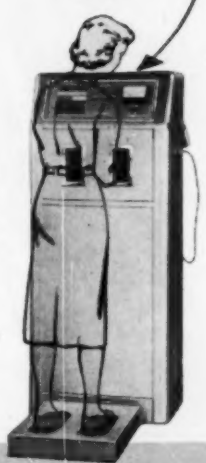
Absolute Counter

Four-π counter (above) permits absolute calibration of radioactive emitters,

- Completely automatic monitoring.
- Safe, error-proof, and easy-to-use.
- Wide range of warning levels.
- Positive warning of incomplete check.
- Includes external clothing probe.

Model HSM-10 provides completely automatic detection and measurement of beta-gamma contamination on the back and palm of each hand and the bottom surfaces of both shoes. No skill is required in its operation. The user simply follows the instructions on the illuminated multi-colored panels at the top of the instrument. The Model HSM-10 employs the decade scaling principle and provides register readouts for error-proof counting. It offers an unusually wide range of operating limits and warning levels and thus can serve any health physics requirement.

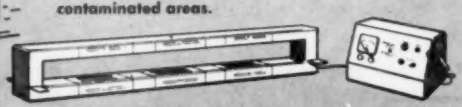
Write for Bulletin No. 167



2 NEW T/A MONITORS!

PPM-8 PORTAL MONITOR provides a quick, efficient economical method of "head to toe" monitoring of personnel entering or leaving a controlled area, and thus prevents the spread of contamination.

LIM-18 LAUNDRY INSPECTION MONITOR is a simplified low-cost instrument for monitoring clothing and equipment worn in beta/gamma contaminated areas.



Write for Bulletin No. 168

TA

TECHNICAL ASSOCIATES

140 WEST PROVIDENCIA AVENUE • BURBANK, CALIFORNIA

ANTON

Neutron and Gamma Detectors for Naval Reactors

- **Meet requirements of Mil-Std-167 and Mil-S-901 for vibration and shock**
- **Advanced, high temperature, watertight detectors available**
- **Delivery from continuous production at economical cost**

SEND FOR FREE DATA NOW!

Anton 818/7087 Multi-element High Sensitivity Neutron Detector

Anton 807/6377 Electrically Compensated Ionization Chamber

Anton 813/6937 Uncompensated Ionization Chamber

Anton 812/6375 Duo-Range Fission Chamber

Anton 805/6307 Neutron Proportional Counter

Anton Boiler-Leak Gamma Detector

Anton 302/5960 Gamma Detector

ANTON ELECTRONIC LABORATORIES, INC., 1226 Flushing Avenue, Brooklyn 37, N. Y.

☐ Send me FREE Neutron Detector Catalog
☐ Send me FREE Alpha, Beta, Gamma Detector Catalog

NAME.....

CO. OR INSTIT.....

ADDRESS.....

CITY..... STATE.....

ANTON ELECTRONIC LABORATORIES, INC.

1226 FLUSHING AVE., BROOKLYN 37, N. Y.

primarily α and β. Logically derived mathematical conversion corrections are used. Features include full efficiency hemispherical chambers with loop center-wire assemblies, separate transistorized amplifier discriminators for each hemisphere and built-in gas flow control. Input selector permits signals from either or both hemispheres, simultaneously or from a coincidence circuit.—Nuclear Measurements Corp., 2460 No. Arlington Ave., Indianapolis 18, Ind.

Ultrasonic Cleaner

Ultrasonic cleaner has 250-w average output with 1,000-w peaks. Tank is 9 × 12 in. × 12-in. deep and has 44% of bottom covered with driving elements.—National Ultrasonic Corp., 111 Montgomery Ave., Irvington 11, N. J.

Environmental Test Chamber

Chamber with 3-ft³ volume has controlled temperature range from 180° F to −80° F and altitude control from sea level to 100,000 ft; 1-in.-dia through-tube permits insertion of radioactive source for radiation experiments.—Cincinnati Sub Zero Products, 3932 Reading Rd., Cincinnati, Ohio.

Single Crystals

Randomly-oriented single crystal specimens in Al, Cd, Cu, Pb, Ni, Ag, Sn and Zn are available as off-the-shelf items in many standard sizes and shapes. In addition, practically any crystal orientation, unusual shapes and bicrystals and tricrystals can be supplied.—Flow Corp., 85 Mystic St., Arlington 74, Mass.

Gamma-Ray Dosimeter

Radioluminescent glass, weighing only 1 oz, records exposure to radiation cumulatively from 10 to 600 r. Accuracy is ±20% from 0.08 to 1.5 Mev. Companion computer-indicator operates on five 1½-v flashlight batteries and has ultraviolet lamp and photomultiplier tube. Scales are 0–200 and 0–600 r.—Specialty Electronics Development Corp., Syosset, N. Y.

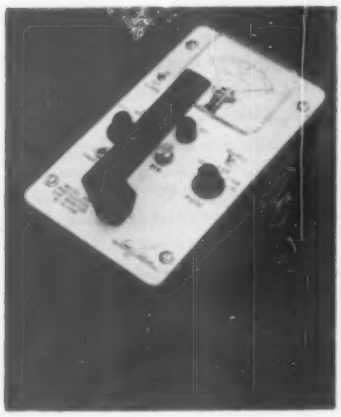
Counting Instruments

Scaler, high-voltage supply and amplifier/selector are first instruments in new series of budget-priced counting

instruments featuring printed-circuit plug-in boards and identical power pack in all units.—Isotope Development Ltd., Beenham Grange, Aldermaston Wharf, Berks, England.

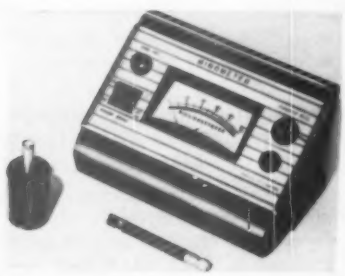
Low-Energy Gamma Detector

Low-energy gamma detector is designed primarily to detect small amounts of Pu^{239}; with slight modifications it can detect Am^{95} and U^{235}. NaI scintillator is used. Sensitivity for direct Pu radiation is 15 cps/mc and about 0.2% of this for background radiation.—Plessey Nucleonics Ltd., Ilford, Essex, England.



Radioactive Gas Monitor

Model 149 gas monitor (above) can detect H^3, Rn and Kr^{85}. Features include push-button calibration source, rechargeable batteries and automatic battery voltage check.—Land-Air, Inc., I & E Div., 2133 Adams Ave., San Leandro, Calif.



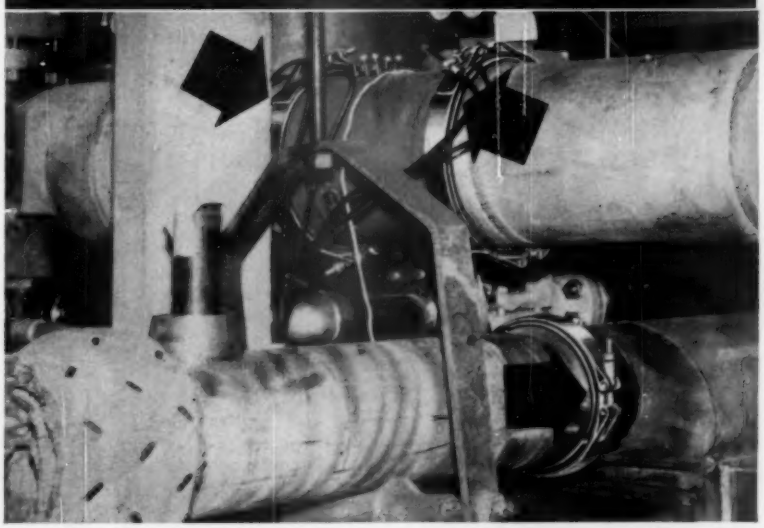
Charger-Reader

Charger-reader (above) permits immediate readout of indirect-reading pocket dosimeters and stray-radiation chambers. Log of instrument, which has 0–20-mr and 0–200-mr range settings, can be used for legal records. Standardized charging voltage permits charger-recorders to be used interchangeably.—The Victoreen Instrument Co., 5806 Hough Ave., Cleveland 3, Ohio.

MARMAN CONOSEAL Joints

Chosen for Critical Piping

ON ARMY CLOSED CYCLE GAS TURBINE TEST FACILITIES AT FORT BELVOIR, VA.



Marman CONOSEAL Joints on a closed cycle gas turbine installation now under construction by the U.S. Army Engineer Reactors Group at Fort Belvoir, Virginia.

The All-Metal Marman CONOSEAL Joint is designed to provide absolute dependability in connecting and sealing piping and tubing. It can be used on gas, liquid, vacuum and liquid metal systems under these pressure and temperature extremes:

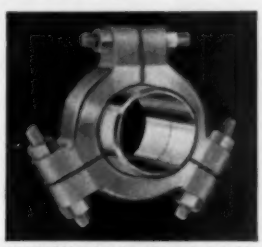
−450°F. to +2000°F.
full vacuum to 20,000 psig.

Through the mechanical advantage of its unique metal gasket, the CONOSEAL Joint also withstands linear deflections up to 1/16" without leakage.

This gasket is designed to yield within the assembly of two mating flanges. Compressed radially and axially, the gasket is completely confined and acts, literally, as a fluid seal. Although 100% metal-to-metal contact is made, this gasket action does not brinell the flange faces. Thus, the joint can be disassembled and reassembled without flange replacement.

Lightweight and compact, the CONOSEAL is available in various configurations to meet a wide range of applications. Write today for your copy of the new CONOSEAL catalog.

CONOSEAL is an Aeroquip Trademark



CONOSEAL Joints have been designed in pipe sizes from ½" to 36" and fabricated with materials such as Zircaloy (reactor grade), 400 and 300 Series stainless steel, nickel steels, mild and low alloy steels and aluminum.

Aeroquip
REG. TRADEMARK

MARMAN DIVISION

11214 EXPOSITION BLVD., LOS ANGELES, CALIFORNIA
IN CANADA: AEROQUIP (CANADA) LTD., TORONTO 19, ONTARIO
Marman Products are Covered by U.S. and Foreign Patents and Other Patents Pending

PHILIPS

equipment for Nuclear Physics and Atomic Energy

Transistorized Pocket Radiation Monitor type PW 4014

- Synchro-cyclotrons for various final energies.
- Cockcroft-Walton accelerators.
- Generators for very high d.c. voltages.
- Linear electron accelerators.
- Reactor control instrumentation.
- Radiation measuring and detection equipment.
- Civil defence instruments.
- Area monitoring instrumentation.
- Geiger counter tubes.
- Photomultipliers.
- Radio-active isotopes.
- Air & gas liqueliers.
- Vacuum measuring equipment.

Outstanding features such as:

- Lowest measuring range: 0-3 mr/h (Ra-γ)
- Provision for connecting separate G.M. Probes and earphone
- Low power consumption
- Printed wiring
- Tropic and waterproof construction

make this new all-transistorized pocket radiation monitor-incorporating the rugged Philips Geiger Müller counter tube type 18503 the ideal instrument for measuring and locating radioactivity

PHILIPS

Nuclear Equipment

For further information please apply to one of the following addresses:

N.V. PHILIPS' GLOEILAMPENFABRIEKEN, Scientific Equipment Department, Eindhoven-Holland
RESEARCH & CONTROL INSTRUMENTS LTD., Instrument House, 207/215, King's Cross Road, London WC1
PHILIPS ELECTRONICS INC., Instruments Division, 750 South Fulton Avenue, Mount Vernon N.Y. U.S.A.

LITERATURE AVAILABLE

Butterfly valve. Bulletin 10, 30 pp.; Henry Pratt Co., 319 W. Van Buren St., Chicago 7, Ill.

Solenoid valves. 14 pp.; Automatic Switch Co., Florham Park, N. J.

Valves. Bulletin A-155, 178 pp.; Associated Valve Co., 337 W. Walnut St., North Wales, Penna.

Beryllium oxide. 8 pp.; BeO crucibles. Data sheet; The Beryllium Corp., Reading, Penna.

Recording annunciator. Bulletin 102A, 4 pp.; Panalarm Div., Panellit, Inc., 7401 N. Hamlin Ave., Skokie, Ill.

Delay lines. Bulletin DL 1159, 2 pp.; Valor Instruments, Inc., 13214 Crenshaw Blvd., Gardena, Calif.

Graphite thermowells. 2 pp.; Falls Industries, Inc., Aurora Road, Solon, Ohio.

Radiation-equivalent manikins. 16 pp.; Atomic Accessories Inc., 244-02 Jamaica Ave., Bellerose 26, N. Y.

Linear amplifier. Model 851, 2 pp.; The Victoreen Instrument Co., 5806 Hough Ave., Cleveland 3, Ohio.

Industrial models. 32 pp.; Atkins & Merrill Inc., Sudbury, Mass.

Miniature pulse transformers. 18 pp.; PCA Electronics, Inc., 16799 Schoenborn St., Sepulveda, Calif.

Mass-spectrometer leak detector. Bulletin GEZ-2939, 12 pp.; General Electric Co., Schenectady 5, N. Y.

Millimicrosecond sampler. 14 pp.; **Pulse generator.** 2 pp.; Lumatron Electronics, Inc., 68 Urban Ave., Westbury, L. I., N. Y.

Pulse transformer. Catalog C202, 21 pp.; Pulse Engineering, Inc., 560 Robert Ave., Santa Clara, Calif.

Electronic fittings. 54 pp.; Atlas E-E Corp., 47 Prospect St., Woburn, Mass.

Magnetic clutches. 18 pp.; PIC Design Corp., 477 Atlantic Ave., E. Rockaway, L. I., N. Y.

Solenoid valves. 20 pp.; Magnatrol Valve Co., 60 Fifth Ave., Hawthorne, N. J.

Liquid-helium dewars. 44 pp.; Hofman Laboratories, Inc., Hillside, N. J.

Cold-cathode vacuum gage. 2 pp.; Vacuum Instrument Corp., Stepar Place, Huntington Station, N. Y.

Boiler-water gages, high pressure. 2 pp.; Jerguson Gage & Valve Co., 80 Adams St., Burlington, Mass.

Butterfly valves. Bulletin 50-1, 4 pp.; Continental Equipment Co., Div. of Fisher Governor Co., Coraopolis, Penna.

Synchronous and servomotors. Bulletins S 900-6 and 7, 12 pp.; Minneapolis-Honeywell, Wayne and Windrim Aves., Phila. 44, Penna.

Pneumatic temperature control. Bulletin 152, 2 pp.; Burling Instrument Co., 16 River Rd., Chatham, N. J.

Recorders. Bulletin GEA-6933, 12 pp.; General Electric Co., Schenectady 5, N. Y.

Gate valves. 4 pp.; Whittaker Controls Div., Telecomputing Corp., 915 N. Citrus, Los Angeles, Calif.

Synchronous motors. Bulletin SS 459, 11 pp.; Electric Co., Bristol, Conn.

Special nuclear systems. Company Information; Atomium Corp., 940 Main St., Waltham 54, Mass.

Vacuum recording balance. 4 pp.; Wm. Ainsworth & Sons, Inc., 2151 Lawrence St., Denver 5, Colo.

Argon leak detection station. 2 pp.; Vacuum Instrument Corp., Huntington Station, N. Y.

Semiconductor directory. Edition No. 5.; **Understanding transistors.** 64 pp.; Allied Radio Corp., 100 N. Western Ave., Chicago 80, Ill.

Thermocouples. 50 pp.; Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia 44, Pa.

Reactor control rod drives. 4 pp.; General Electric Co., Atomic Power Equipment Dept., 2151 S. First St., San Jose, Calif.

Decade counting units. 4 pp.; Computer-Measurements Corp., 5528 Vineland Ave., No. Hollywood, Calif.

DC power supplies. 2 pp.; Gow-Mac Instrument Co., 100 Kings Rd., Madison, N. J.

0–2000 volt power supply. 2 pp.; Gyra Electronics Corp., Washington & Elm Sts., P. O. Box 184, La Grange, Ill.

Galvanometer & amplifier. Data Sheet 14-10, 2 pp.; Kintel Div., Cohu Electronics, Inc., Box 623, San Diego 12, Calif.

Scientific & test instruments. Catalog G-10, 48 pp.; Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.

Gamma radiography. 24 pp.; Budd Co., Nuclear Systems Div., Philadelphia 32, Pa.

Nondestructive testing systems. 4 pp.; Magnaflux Corp., 7300 W. Lawrence Ave., Chicago 31, Ill.

Instrumentation for process industries. 11 pp.; Industrial Nucleonics Corp., Columbus 14, Ohio.

Analytical instruments. 8 pp.; Jarrell-Ash Co., 26 Farwell St., Newtonville 60, Mass.

Annunciator systems. Catalog 100C, 51 pp. **Instrumentation systems.** Bulletin 107, 15 pp.; Panellit Service Corp., 7401 N. Hamlin Ave., Skokie, Ill.

Self-policing annunciator systems. Catalog 659, Scam Instrument Corp., Chicago, Ill.

Recorder for instrumentation. 12 pp.; Ampex Corp., 934 Charter St., Redwood City, Calif.

Windowless 4π chromatogram scanner. 2 pp.; Atomic Accessories Inc., 244-02 Jamaica Ave., Bellerose 26, N. Y.

Recorder reader and data products. 8 pp.; Benson-Lehner Corp., 11930 W. Olympic Blvd., Los Angeles 64, Calif.

NEW Scintillation Detectors

- NE810 Alpha Particle Detector, Consisting of .0005" sheet of plastic phosphor NE102 on a clear plastic base. This detector provides fast decay time, low gamma sensitivity and modest resolution.
- NE812 Hollow Plastic Scintillator for Beta Ray Spectroscopy and for multiple tracer studies of Beta emitters.
- NE813 Gamma Flow Detector for continuous monitoring of gamma effluents in aqueous or organic solutions.
- NE219 Liquid Scintillator for Beta counting of filter paper chromatograms and direct counting on filter paper.

Other products include Plastic Phosphor NE102 fast and slow neutron detectors, and loaded liquid scintillators.

NUCLEAR ENTERPRISES LTD.
1750 Pembina Highway
WINNIPEG 9, CANADA
Associate Co.: Nuclear Enterprises (G.B.) Ltd.
Sighthill, Edinburgh 11, Scotland

JUST OUT . . .

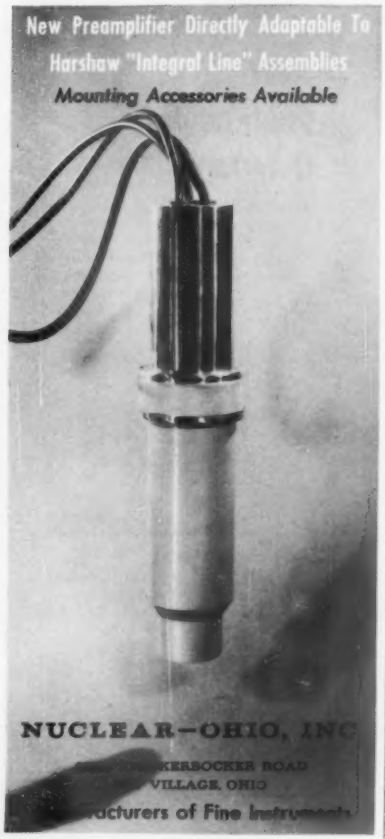
if you want to buy products or need more data in the NUCLEONICS industry . . .

then here is your point of information

NUCLEONICS 1959 BUYERS' GUIDE ISSUE

Expanded, up-dated, accurate, complete, 1959–1960

NUCLEONICS BUYERS' GUIDE Issue
A McGraw-Hill Publication
330 West 42nd Street, N.Y. 36, N.Y.



INDUSTRY NOTES

• **Combustion Engineering** will move its headquarters from New York City to Windsor, Conn., this summer. CE now has fuel-fabrication and other nuclear facilities at Windsor, including the SIC submarine reactor prototype.

• **Atomic Associates** and **Atomic Accessories,** both subsidiaries of **Baird-Atomic,** have moved into new, larger headquarters at 811 W. Merrick Road, Valley Stream, Long Island. Company officials said the move was dictated by rising sales.

• Controlling interest in **Griscom-Russell Co.,** manufacturer of heat exchangers, has passed from General Precision, Inc., to Hamilton-Thomas Corp., Hamilton, Ohio. Hamilton-Thomas also controls **C. H. Wheeler Manufacturing Co.,** Philadelphia, another supplier of equipment to the nuclear power industry.

• **Chesterfield Tube Co., Ltd.,** subsidiary of the British firm Tube Investments, has reached a "know-how" agreement with **Superior Tube Co.,** Norristown, Pa., on the manufacture of beryllium. The two firms will exchange information on beryllium tube drawing and will coordinate their research programs. Chesterfield Tube has had some $700,000 in beryllium tube orders from the U. K. Atomic Energy Authority and other nuclear customers.

• AEC has extended from March 31, 1962, to Dec. 31, 1966, the termination date of its uranium-concentrate contract with the **Anaconda Co.** The agreement covers Anaconda's Bluewater, N. M., mill, permitting it to process up to 3,000 tons ore/day on a six-day week. AEC has also given a U purchase contract to **Cotter Corp.,** permitting upsizing of Cotter's Canon City, Colo., plant from 50 tons ore/day to 200 tons/day.

• West Coast offices have been opened by two major materials suppliers to the nucleonics industry. **Beryllium Corp.** has assigned Ward Baxter, Jr., to manage its regional sales office at 401 N. Brand Blvd., Glendale 4, Calif.; Beryllium Corp. has also announced a new expansion program at its Nuclear div., Hazleton, Pa. **Wolverine Tube div. of Calumet & Hecla** has established offices in Los Angeles and San Francisco.

• **Kewaunee Mfg. Co.,** maker of glove boxes and other nuclear equipment, has established a new division, Kewaunee Scientific Equipment, at company headquarters, Adrian, Mich. The division will specialize in the design and manufacture of highly specialized equipment.

NEW BUSINESS. Major contract awards to **Nuclear Materials and Equipment Corp.** include: 1. From **Combustion Engineering,** $100,000-plus fuel-pellet order for a nuclear superheat critical facility (delivery in February and March); and 2. From **General Atomic,** an order of about $75,000 for graphite blocks impregnated with highly enriched U_3O_8 for the critical facility to be built in the High Temperature Gas-cooled Reactor program (delivery this spring). . . . **Leeds & Northrup** is supplying reactor-control instrumentation for the 5,000-kw research reactor ordered from Babcock & Wilcox by Italy's Centro Atonomo Militare Energia Nucleare (CAMEN).

FINANCIAL. A sharp drop in earnings was reported by **Baird-Atomic** for the fiscal year ended Sept. 31; earnings dropped to $37,000 (5 cents/share) from $122,000 (17 cents/share) in the preceding year. Sales, however, rose from $7-million in fiscal 1958 to $8.3-million in 1959; B-A officials have predicted a further rise in sales during fiscal 1960 to $12-million (NU, Oct. '59, 27). . . . **Volk Radiochemical Co.** reported earnings of $3,842 for the fiscal year ended Aug. 31 on sales of $275,134; sales were up from $206,740 a year earlier but earnings were down more than 50% from $8,893. President Murray E. Volk predicted sales of more than $400,000 in the current fiscal year, reflecting, in part, the recent acquisition of **Atomic Corp. of America,** Los Angeles, and the medical radioisotope business of **Atomic Research Laboratory,** also in Los Angeles. . . . **High Voltage Engineering Corp.** paid a 3% stock dividend Jan. 21 to stockholders of record Dec. 30; the dividend replaces a 10-cent cash dividend paid annually for ten years. . . . Merger of **Anton Electronics** and **Inter-Continental Mfg. Co.** into **Anton-IMCO Electronics, Inc.,** was approved last month by stockholders of U. S. Hoffman, former parent firm for both (NU, Oct. '59, 128).

NEW! BENDIX
200mr
DOSIMETER

★ MEASURES INTEGRATED EXPOSURES TO X AND GAMMA RAYS

★ APPROVED FOR MATCHING FUND PROCUREMENT BY OCDM

Product of famous Bendix precision craftsmanship, this 200mr Dosimeter offers the utmost quality and reliability. Weighs less than 1½ ounces. Only 4¼" long and 1⅞" in diameter. Highly shock resistance. Write BENDIX AVIATION CORP., Dept. G-2, 3130 Wasson Road, Cincinnati 8, Ohio.

Cincinnati Division
Cincinnati, Ohio

Bendix

Canadian Sales: Computing Devices of Canada, Ltd., Box 508, Ottawa 4, Ontario. Export Sales: Bendix International, 205 E. 42nd Street, New York 17, N. Y.

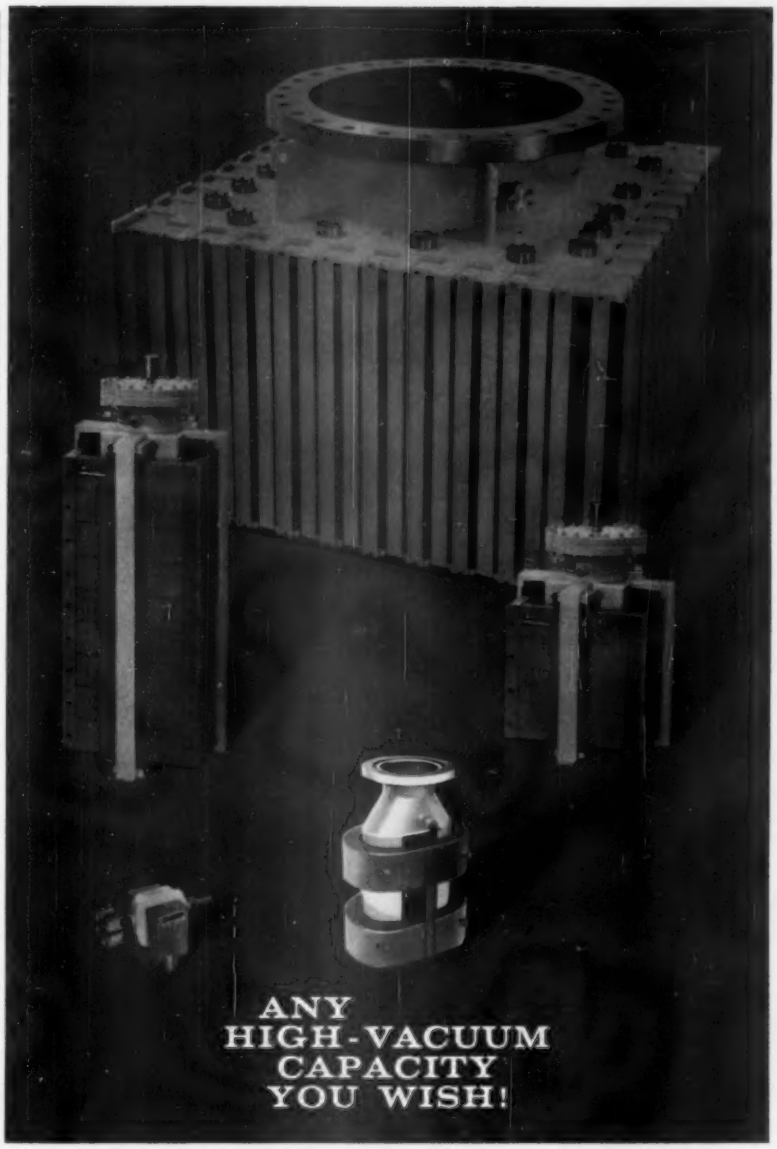
NUCLEAR CAMPUS

CAMPUS GRANTS. Four institutions have received grants-in-aid for nuclear training or research programs: **1.** General Motors has given $500,000 to the Phoenix Memorial Project of the **Univ. of Michigan.** Subsequently, Phoenix created an Institute of Industrial Health, and $350,000 of the GM grant will go to this group; the remaining $150,000 will be used for nuclear research. The GM contribution brought to $760,000 the total pledged toward a $2-million drive to sustain Phoenix for five more years. **2.** General Electric has given the **Univ. of Arizona's College of Engineering** a grant of GE equipment (value not specified) for several departments, including two divisions of the Nuclear Engineering dept.; the equipment will be used for both reactor and radioisotope programs. **3.** The National Science Foundation has given **Rensselaer Polytechnic Institute** $24,700 for research into nuclear reactions induced by fast neutrons; RPI will use its Cockcroft-Walton accelerator as the neutron source. **4.** AEC has given **Syracuse Univ.** a $10,200 grant for the purchase of radiation detectors and accessory teaching equipment for radiation biology; the university is a contractor to the Army Surgeon General on the biological effects of irradiated food.

ISOTOPE AWARDS. Seven schools have been given equipment grants by AEC to bolster their instructional capability in radioisotope technology. Awards totalling $50,000 went to **Roosevelt Univ.** ($8,996), **College of Puget Sound** ($8,258), **Providence College** ($8,000), **Earlham College** ($6,990), **New York City Community College** ($6,756), **Dartmouth College** ($6,000) and **Davidson College** ($5,000). AEC's backlog of isotope equipment requests is more than $2-million but only $50,000 was available this fiscal year. The program stresses grants for small colleges.

COURSES. The Robert A. Taft Sanitary Engineering Center of the U. S. Public Health Service, Cincinnati, is offering **radionuclides in foods** Apr. 18–29.

Philips Electronic Instruments is offering its **Norelco X-ray School** in New York (Henry Hudson Hotel) Feb. 15–19. Contact Vern W. Palen, Philips, 750 S. Fulton Ave., Mount Vernon, N. Y.



The 40 liter/second Vaclon® High Vacuum Pump, emphasized above, is just one of a great variety of Varian Vaclon Pump sizes available from stock. These include ½, 1, 5, 40, 100, 140, 280, 1000, 3000, 5000 and 10,000 liter/second capacities. Other sizes available on custom order.

All these pumps give extremely clean vacuums to below 10^{-10} mm Hg, have no moving parts or fluids, and operate without attention or service.

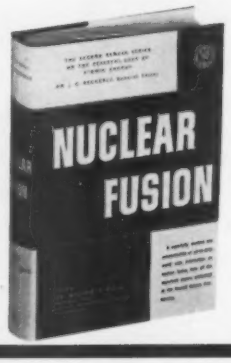
The Vaclon High Vacuum Pump is a fully electronic device and is a Varian "First." Unique both in principle and advantages, it has been accepted as an efficient, reliable laboratory and production tool by industries throughout the world.

A comprehensive brochure and technical data sheets are available by writing Vacuum Products Division.

COMPLETE VARIAN VACION HIGH-VACUUM SYSTEM

VARIAN associates
PALO ALTO 41, CALIFORNIA
Representatives throughout the world

KLYSTRONS, WAVE TUBES, GAS SWITCHING TUBES, MAGNETRONS, HIGH VACUUM EQUIPMENT, LINEAR ACCELERATORS, MICROWAVE SYSTEM COMPONENTS, NMR & EPR SPECTROMETERS, MAGNETS, MAGNETOMETERS, STALOS, POWER AMPLIFIERS, GRAPHIC RECORDERS, RESEARCH AND DEVELOPMENT SERVICES



NUCLEAR FUSION

The Second Geneva Series on the Peaceful Uses of Atomic Energy

Edited by DR. WILLIAM P. ALLIS, Professor of Physics, Massachusetts Institute of Technology and Consultant, Los Alamos Scientific Laboratory

Here in a carefully worked out presentation are the most significant ideas on fusion presented at the 1958 conference in Geneva. Contributors from some eleven nations presented papers and in this convenient volume duplications have been removed, clarifications added where necessary and the subject matter helpfully indexed.

Following a general survey of world-wide controlled thermonuclear research, plasma properties are discussed including diagnostics, waves equilibrium and stability and dynamics. Coverage of the types of thermonuclear machines such as the pyrotron, the stellarator, injection machines, sustained and dynamic pinches occupy over one-half of the book.

All who are concerned with the solid facts behind the dream of unlimited nuclear power will find on these pages a compact, usable one volume guide to the present status of nuclear fusion.

450 pp. $12.50

HARMFUL EFFECTS OF IONISING RADIATIONS

by Ethel Browning

160 pp. $3.00

BASIC PRINCIPLES IN NUCLEAR SCIENCE AND REACTORS

by Alan M. Jacobs, Donald E. Kline, Forrest J. Remick

250 pp. prob. $7.50

FREE EXAMINATION COUPON

D. VAN NOSTRAND COMPANY, INC.
120 Alexander Street Dept. NA
Princeton, New Jersey

Send me for ten days free examination

NUCLEAR FUSION (Allis) $12.50
HARMFUL EFFECTS OF IONISING RADIATIONS (Browning) $3.00
BASIC PRINCIPLES IN NUCLEAR SCIENCE AND REACTORS (Jacobs) prob. $7.50

Within 10 days I will remit purchase price plus small delivery cost or return book and owe nothing.

Name .....

Address .....

City .....Zone.....State.....

Save! Remit with order and we pay delivery cost. Same return guarantee. In Canada: 25 Hollinger Rd., Toronto 16. Price slightly higher.

NUCLEAR CALENDAR

Feb. 10–11—Symposium on Gas-cooled Reactors, sponsored by Franklin Institute and Delaware Valley Section, American Nuclear Society, Philadelphia. To cover both U. S. and U. K. programs and include a British speaker at banquet Feb. 10. Contact Francis L. Jackson, FI, Philadelphia 3.

Feb. 11—AEC Information Meeting on Aircraft Nuclear Propulsion, Oak Ridge National Laboratory, Oak Ridge, Tenn. Contact R. A. Charpie, ORNL, P. O. Box Y, Oak Ridge.

Feb. 14–18—Annual Meeting of American Institute of Mining, Metallurgical and Petroleum Engineers, New York. Contact AIMMPE, 29 W. 39th St., N. Y. 18, N. Y.

Feb. 25–26—7th Scintillation Counter Symposium, Washington, D. C. (*Shoreham*). Contact G. T. Reynolds, Princeton Univ., Princeton, N. J.

March 18–19—Annual Meeting of Southeastern Chapter, Society of Nuclear Medicine, Oak Ridge, Tenn. Contact Granville Kyker, ORINS Medical div., Oak Ridge.

March 19–20—Direct conversion of nuclear energy, symposium of Pittsburgh section, American Nuclear Society, at Pittsburgh (*Mellon Institute*). Contact George Weddell, Westinghouse, Box 1468, Pittsburgh 30.

March 23–24—Symposium on Optical Spectrometric Measurements of High Temperatures, sponsored by Applied Science Laboratories of Univ. of Chicago, Jarrell-Ash Co. and National Science Foundation, Chicago (*Univ. of Chicago*). Program includes papers on plasma. Contact Frederick Brech, c/o Laboratories for Applied Science, Univ. of Chicago, 6220 S. Drexel Ave., Chicago 37, Ill.

March 29–31—22nd Annual American Power Conference, sponsored by Illinois Institute of Technology and several societies and schools, Chicago (*Sherman*). Contact R. A. Budenholzer, Mechanical Engineering dept., IIT, 3300 Federal St., Chicago 16.

March 30–31—Workshop on Industrial Uses of Radioisotopes, co-sponsored by Connecticut Power & Light, Hartford Electric Light, Housatonic Public Service, United Illuminating, AEC and Yale Univ., New Haven, Conn. (*Yale*). Contact E. B. Haskell, United Illuminating, New Haven 6.

April 3–8—6th Nuclear Congress, New York City (*Coliseum*). Includes 6th Nuclear Engineering & Science Conference, 8th Atomic Energy in Industry Conference and 6th International Atomic Exposition. Contact E. B. Gunyou, Curtiss-Wright Corp., Princeton, N. J.

Apr. 19–22—International Symposium on the Metallurgy of Plutonium, Grenoble, France. Sponsored by French Society for Metallurgy. Contact Max Dupont, 25 rue de Clichy, Paris 9, France.

May 3–6—Fuel Element Symposium sponsored by International Atomic Energy Agency, Vienna. **June 7–13**—IAEA Symposium on Radiation Dosimetry, Vienna. **Aug. 8–13**—IAEA Symposium on Ionizing Radiation Effects on Seeds and Improvement of Crops, Karlsruhe, Germany. Contact IAEA, 11–13 Kartner Ring, Vienna 1.

May 9–13—Instrument Society of America, San Francisco. For papers on measurement and control instruments contact Martin E. Kantor, c/o General Atomic, P. O. Box 608, San Diego 12, Calif.

May 12—Advanced Propulsion Reactor concepts, unclassified session at American Rocket Society semiannual meeting, at Los Angeles (*Ambassador*). Contact C. J. Wang, c/o Space Technology Labs, Box 95001, Los Angeles 45.

June 12–15—Annual Meeting of American Nuclear Society, Chicago (*Palmer House*). Contact Octave J. DuTemple, 86 E. Randolph St., Chic. 1.

June 22–25—Annual meeting, Society of Nuclear Medicine, Estes Park, Colo. Contact Thad P. Sears, Denver, Colo.

June 29–July 1—Annual meeting, Health Physics Society, Boston (*Statler-Hilton*). Contact J. W. McCaslin, 1808 Rose St., Berkeley, Calif.

Aug. 11—AEC information meeting on small reactors, Oak Ridge. Contact R. A. Charpie, ORNL, Box 4, Oak Ridge.

Sept. 13–15—Fifth International Instruments and Measurements Conference, including section on nuclear instrumentation, and an exhibition of commercial instrumentation, Stockholm. Contact H. von Koch, Royal Institute of Technology, Stockholm 70, Sweden.

Oct. 20–22—2nd Youth Conference on the Atom (*Museum of Sci. & Ind.*), Chicago. Contact Bozell & Jacobs, 2 W. 45th St., N. Y. 36, N. Y.

Dec. 11–16—American Nuclear Society–Atomic Industrial Forum joint meeting, San Francisco (*Mark Hopkins* and *Fairmont*). **12–15th** Atomfair West, first West Coast nuclear industrial exposition (*Masonic Memorial Building*). Contact W. Kelly Woods, Vallecitos Atomic Laboratory, Pleasanton, Calif., for ANS program; Edwin Wiggin, AIF, 3 E. 54 St., N. Y. 22, for Forum program; Dan Scherer, AIF, for Atomfair.

NEWSMAKERS

Maj. Reuben Pomerantz, associated with the Army's food irradiation program since its inception, has been named acting scientific director for research and development, U. S. Army Quartermaster Research & Engineering Center Laboratories, Natick, Mass.

James F. Schumar has left Argonne National Laboratory to join General Atomic as chairman of the Metallurgy dept., John Jay Hopkins Laboratory. One of the nation's leading metallurgists, Schumar had been associate director of the Metallurgy dept. at Argonne. His long record of achievement in the nuclear-materials field goes back to some of the nation's first reactors, including materials development for the Hanford production plants.

Schumar

The American Institute of Electrical Engineers has awarded its 1959 Edison Medal to **James F. Fairman,** senior vice-president, Consolidated Edison Co. He was cited, among other things, "for farsighted leadership in atomic power development."

Frank B. Jewett, Jr., executive vice-president of Vitro Corp. of America, has been elected president of the company. He has taken over from **J. Carlton Ward, Jr.,** who had been chief executive officer of the company since 1953. Ward has succeeded **Charles S. Payson** as board chairman and Payson has been elected chairman of the executive committee of the board. Jewett joined Vitro in 1956 after eight years at General Mills, where he was managing director for engineering, research and development. His election was another step in a corporate realignment at Vitro which has included in recent months the dissolution of some activities and the consolidation of others (NU, Dec. '59, 135).

Jewett

Ward

R. S. Landauer, Jr., & Co. has named **Allan Bird** to a new post: sales development manager.

Controls for Radiation has promoted six employees: **Richard C. Fix** and **Pasquale F. Russo** to assistant technical directors; **Thomas G. Martin** to head, Radiological Safety dept.; **Arnold S. Levine** to head, Analytical Chemistry dept.; **Leo F. Foley** to head, Low-level Radiochemistry dept.; and **Robert E. O'Brien** to head, Contract Sales.

A. B. Van Rennes, supervisor of the nuclear technology group at Bendix Aviation's Research Laboratories div., has joined United Research Inc. as vice-president in charge of the Technical div. Van Rennes is chairman of the Professional Group on Nuclear Science, Institute of Radio Engineers, and a member of standards committees of the American Nuclear Society and American Standards Assn.

Van Rennes

Wingate A. Lambertson, a specialist in nuclear ceramics and high-temperature research, has been named manager, Engineering branch, Research and Development div. of Carborundum Co.

New radiation safety officer for the Manufacturing dept., Babcock and Wilcox, is **P. M. Frazier,** former chief of radiation and plant safety at B & W's Lynchburg, Va., installation.

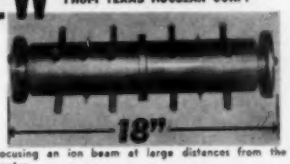
Howard D. Philipp has been selected to direct a nuclear engineering group established by Niagara Mohawk Power Corp. The new group will handle analyses of possible nuclear plants for the Niagara Mohawk system. Philipp had been on leave of absence from the company since 1953, when he joined Atomic Power Development Associates, conceptual designers of the Fermi fast-breeder reactor.

John A. Wheeler of Princeton Univ. has been named to the Board of Trustees, Battelle Memorial Institute. Wheeler has done important work in several areas of nucleonics.

WHERE TO BUY

Featuring additional products, specialties and services for Atomic Power, Nuclear Engineering and Applied Radiation.

NEW FROM TEXAS NUCLEAR CORP.



- For focusing an ion beam at large distances from the accelerator
- Cancels astigmatism produced by analyzing magnet
- Increases useful ion beam intensity

TEXAS NUCLEAR CORPORATION

P. O. Box 9267 (Dept. D Austin 17, Texas

Larger Sizes Now Available

Hi-D® LEAD GLASS WINDOWS

For use in steel, lead, and concrete walls.

Send for Circular GS-7

PENBERTHY INSTRUMENT CO.

4301 6th AVE. SOUTH • SEATTLE 8, WASH.

PROFESSIONAL SERVICES

ASTRA, Inc.

For Your Atomic Energy Problems

Nuclear Analyses, Reactor Specifications and Designs, Radiation Shielding Design and Analysis, Criticality Hazards Studies, Thermodynamics and Heat Transfer Analysis, Facilities Planning, Health Physics.

P. O. Box 226 Raleigh, North Carolina
VAnce 8-4386 CABLE: "ASTRA"

INTERNUCLEAR COMPANY

Nuclear consultants, engineers, and designers

Economics of Nuclear Power, Reactor Analysis and Design, Shielding, Special Applications

Clayton 5 Missouri

NUCLEAR REACTOR ASSOCIATES

Nuclear Engineering & Economic Consultants

General economic consulting—Marketing—Nuclear, metallurgical, mechanical, architectural and industrial engineering.

436 Farmington Avenue, Hartford 5, Connecticut

Telephone: ADams 6-3211

Your Inquiries to Advertisers Will Have Special Value . . .

—for you—the advertiser—and the publisher, if you mention this publication. Advertisers value highly this evidence of the publication you read. Satisfied advertisers enable the publisher to secure more advertisers and—more advertisers mean more information on more products or better service—more value—to YOU.

• PHYSICISTS
• ENGINEERS
• METALLURGISTS

For ATOMIC POWER PROGRAMS
on the
San Francisco Peninsula

Advanced Technology Laboratories of American-Standard has urgent requirements for a few select senior nuclear scientists and engineers for key positions on challenging projects:

Physics and Kinetics of the Variable Moderator Reactor.
In conjunction with a critical experiment, advanced methods are being developed for the design of this boiling water reactor.

Design of Mercury Mist Cooled Fast Reactor.
Experimental and analytic work is now in progress for application to the breeder and compact reactor field.

Pressurized Water Reactor Design.
Designs are being developed for small process heat pressurized water reactors.

Application to Missiles and Rockets.
Advanced propulsion and auxiliary power sources are under study.

Advanced Fuel-Element Development.
Uranium and thorium alloys for increased strength and radiation resistance and new types of oxide fuel elements prepared by plasma-jet techniques are being developed.

Thermal Stress Fatigue of Reactor Structural Materials.
A detailed investigation of the factors affecting thermal stress fatigue is in progress.

Immediate Openings for the Following:

1. Senior Nuclear Systems Engineers.
2. Senior Nuclear Engineers for nuclear and thermal analysis.
3. Senior Mechanical Engineer for control rod, core internals, and fuel handling systems.
4. Senior Process System Engineer for heat balance, flow determinations, and design of primary system components.
5. Senior Reactor Physicists for theoretical analysis of critical experiments on the VMR boiling water reactor and mercury mist cooled fast reactors.
6. Senior Metallurgical and Ceramics Engineers for research and development on advanced materials and components for nuclear applications.
7. Senior Materials Engineer for participation on reactor design projects.

A career at ATL offers several distinct advantages:

Stimulating technical challenges.
An informal atmosphere in a medium sized, young organization.
Opportunity for advancement as operations expand.
Encouragement of individual initiative and interest.
Location in the stimulating climate and cultural environment of the San Francisco Bay Area.

Please send your resumes in confidence to:

Dean W. Townsend, Manager
Personnel Administration
Advanced Technology Laboratories
A Division of American-Standard
369 Whisman Road
Mountain View, California

ADVANCED *Technology* LABORATORIES
A DIVISION OF AMERICAN-Standard

NEWSMAKERS

Department starts on page 125

A key figure in the design of Argonne National Laboratory's Zero Gradient Synchrotron, **Martyn H. Foss,** has been appointed associate director of ANL's Particle Accelerator div. Foss conceived the idea for the machine's distinctive feature—a new type of magnet. The ZRS is scheduled to be completed in 1962.

Top post in the Univ. of Michigan's nuclear research program has been given to **Henry J. Gomberg,** who has been named director of the University's Memorial Phoenix Project. Gomberg succeeds Ralph A. Sawyer, vice-president of the University for research. Gomberg will continue as chairman of the Nuclear Engineering dept. in the College of Engineering. In his speech relinquishing the Phoenix post, Sawyer disclosed that the Project intends to enter the controlled fusion field. "We hope to support work on some new approaches to the problem," he said.

W. L. Martwick has succeeded **Earl W. Mills** as chairman of Foster Wheeler Corp. **John E. Kenney** has succeeded Martwick as president.

In a similar top-management shift at Stone & Webster Engineering Corp., **T. Cortlandt Williams** has been elected chairman; **Fred W. Argue,** president; **Alfred L. Hartridge,** financial vice-president and treasurer; and **Arthur J. Good,** vice-president and comptroller.

James R. Brown, formerly an advisory scientist in experimental reactor physics at Westinghouse Bettis, has joined the Atomic Experimental Physics dept. at General Atomic's John Jay Hopkins Laboratory.

Hughes Aircraft Co. has named **Norman A. Baily** a senior staff physicist in the nuclear electronics laboratory, where he will concentrate on medical and radiological applications of linear accelerators and detection devices. Baily had been chief scientist in the Radiation Therapy dept. of Roswell Park Memorial Institute, Buffalo, N. Y.

Nuclear Science and Engineering Corp. has added three men to its marketing staff, more than doubling its size: **Robert Grover, William Werner** and **Martin Ely.**

PHYSICISTS

Opportunities in advanced reactor development at The Knolls Atomic Power Laboratory. The new groups being formed around key members of KAPL's professional staff afford physicists who join us now, unusual opportunities to work in close liaison with acknowledged leaders in reactor technology. Experimental facilities for nuclear investigations at KAPL rank with the finest in the nation and include seven reactor critical assemblies, one of which permits study of core configurations at power reactor temperatures and pressures. You are invited to inquire about the following openings: **Experimental Physicists** to plan, conduct and interpret results of reactor physics experiments. Develop new critical experiments, techniques and analytical methods of solving experimental reactor physics problems. Assist in the formulation and direction of critical experimentation. Should have MS or PhD in Physics. **Analytical Physicists** to interpret physics data and its application to design. Develop theory, analyze phenomena and predict nuclear performance and characteristics of reactors. Should have MS or PhD in Nuclear Engineering or Physics. **Nuclear Analysts** to evaluate reactor nuclear designs, using analytical and machine computational techniques. Predict nuclear performance of reactors. Develop and improve analytical techniques for the solution of nuclear design problems. Qualifications should include MS in Engineering or Physics with experience in nuclear analysis of reactors. **Also Openings in these areas:** Advanced Mathematics / Computer Programming / Controls Development / Coolant Chemistry & Engineering / Electrical Design / Facilities & Construction / Shielding Design / Heat Transfer, Fluid Flow / Instrumentation Development / Mass Spectrometry / Materials Application / Mechanical Design / Physical Metallurgy / Powerplant Equipment / Pressure vessel Design / Radiochemistry / Radiological Engineering / Reactor Plant Operation / Solid State Physics / Stress Analysis / Systems Analysis / Welding & Fabrication / X-Ray Diffraction.

ADVANCED DEGREE PROGRAM KAPL is now considering recent graduates in ME, Met, Met E, ChE, Physics, EE, Nuclear and Marine E for its advanced degree program in nuclear engineering in conjunction with Rensselaer Polytechnic Institute. Applicants should have strong interest in nuclear field and must have graduated in upper 10% of their class. Selection of candidates will be completed by April 1; classes begin September, 1960. Write for further details.

Please forward your resume in confidence, including salary requirement, to Mr. A. J. Scipione, Dept. 48-MB. U.S. Citizenship Required

Knolls Atomic Power Laboratory

OPERATED FOR A.E.C. BY

GENERAL ELECTRIC

SCHENECTADY, N.Y.

Accent Is On The Individual At ALCO . . .

A pioneer designer and manufacturer of nuclear thermal equipment provides many individual opportunities to qualified personnel. Liberal employee benefits including company assistance in furthering educational development at nearby universities. Current programs include the SM-1 operation and Core I loading, SM-1A and PM-2A final engineering and start-up, SM-2 design and development, and Core I procurement.

NUCLEAR ENGINEERS & PHYSICISTS

For small work group assignments within the Reactor Analysis Section

- To perform necessary calculations to establish core nuclear specifications.
- To perform necessary calculations to establish core cooling requirements.
- To perform necessary calculations to establish core shielding requirements.
- To develop and execute engineering programs for analog and digital computers.

College degree with several years' actual experience required.

SOME SUPERVISORY POSITIONS OPEN

Please send complete resume and salary requirements in confidence to: G. Y. Taylor, Administrative Services

ALCO **ALCO PRODUCTS** Incorporated

Schenectady 5, New York

TECHNICAL SALES—C-14

Compounds, encapsulated sources, special nuclear devices—Eastern area. Good chance to grow with expanding small company. Send resume to

SW-3164 Nucleonics
68 Post St., San Francisco 4, Calif.

NUCLEAR ENGINEERS

We are offering opportunities in an expanding division of our firm to graduate Mechanical Engineers experienced in nuclear power generation. We require 3–5 years on atomic energy projects backed by engineering and design for major central station steam power plants.

Communications treated confidentially.

Please send resume to
Warren Garvey
Personnel Manager

GIBBS & HILL, Inc.
Pennsylvania Station
New York 1, New York

ADDRESS BOX NO. REPLIES TO: Box. No. Classified Adv. Div. of this publication. Send to office nearest you.
NEW YORK 36: P. O. BOX 12
CHICAGO 11: 520 N. Michigan Ave.
SAN FRANCISCO 4: 68 Post St.

POSITIONS VACANT

A senior position is available in the Department of Physics in Memorial Center, New York. A qualified hospital physicist is desired who is interested in a combination of teaching, research and application. Interest in research in the fields of x-ray diagnosis and implant dosimetry, or in the medical application of radioactive isotopes would be particularly desirable. An academic appointment is associated with this appointment which also carries with it a favorable salary, retirement plan, and other benefits. For further information, please write Dr. J. S. Laughlin, Department of Physics, Memorial Center, 444 East 68th Street, New York.

Nuclear Engineer for stimulating, maturing assignment that will lift you out of the narrow confines of your present duties. The position, at one of the focal points of the nuclear industry, demands technical competence, articulateness, personal effectiveness, and above all else a sense of excitement about the nuclear field and the age in which we live—don't apply if you don't have these qualities. Salary: competitive. Location: East Coast. Write telling us who you are, what you've done, where you want to go, and what your salary requirements are. P-3442, Nucleonics.

POSITIONS WANTED

Physicist, M.S., additional grad work in biosciences. 3 years experience in mechanical stability and control problems, 5 years in radiological field including health physics, biological use of isotopes and radiation machines, licensing and administration. Prefer Illinois or vicinity. PW-3266, Nucleonics.

Chemical Eng. B. CH. E. 1½ yrs. experience in design of nuclear power plants. PW-3402, Nucleonics.

PLASMA RESEARCH

The growing activities of our Plasma Research group now provides an exceptional opportunity for experienced personnel with advance degrees to conduct theoretical and experimental research on:

- PLASMA PHENOMENA
- ELECTRICAL DISCHARGES IN GASES
- SHOCK WAVE PHENOMENA
- ELECTRON BALLISTICS

A few of the advantages of employment with the Foundation include competitive salaries, creative work atmosphere, air-conditioned facilities, scientifically oriented management, and liberal benefits providing up to four weeks vacation and tuition-free graduate study.

•

For further information concerning employment at ARF, visit our suite at the American Physical Society Meeting (Jan. 27–30) or write to:

A. J. Panerai
ARMOUR RESEARCH FOUNDATION
of Illinois Institute of Technology
10 West 35th Street
Chicago 16, Illinois

Responsible positions now open for

ELECTRONIC EQUIPMENT DEVELOPMENT ENGINEER

Nuclear Instrumentation

There are perhaps only a dozen engineers in the country who combine a knowledge of transistor circuitry with nuclear equipment requirements, particularly to the extent of the outstanding individual contributor who will soon retire from The Knolls Atomic Power Laboratory.

The new man we seek must have significant experience in electronics and be thoroughly familiar with all types of transistor circuits, pulse, D.C., A.C., multivibrators, etc. He must also be well grounded in nuclear equipment such as counters, ion chambers, scalers, pulse-height analyzers, time-of-flight analyzers and related equipment.

This is an opening of high importance, both for KAPL and for a man who prefers to work as a key "individual contributor," assisted closely by two or three less experienced engineers and technicians . . . with a well-equipped laboratory and shop at his disposal.

RADIOLOGICAL ENGINEER

This opening on our professional staff is for a highly qualified engineer or physicist to assume responsibilities for evaluating radiation hazards associated with the design, construction and operation of nuclear facilities. This challenging assignment will pose problems involving consideration of health physics aspects of required radiation monitoring instrumentation, shielding, air cleaning and waste disposal.

Background should include approximately seven years industrial experience, most of it in atomic energy industry, with a substantial record of responsible work in Radiation Protection. Experience in nuclear engineering and reactor safeguards activities helpful. Should have Engineering degree (Chemical, Mechanical or Civil) with nuclear courses.

U.S. Citizenship Required

Reply fully in confidence, including salary requirement, to

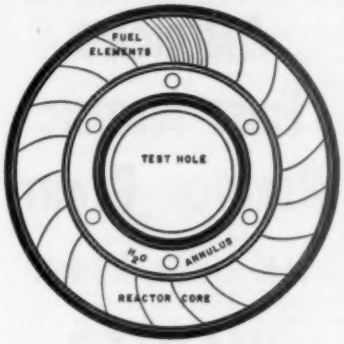
Mr. A. J. Scipione, Dept. 48-MBA.

Knolls Atomic Power Laboratory
OPERATED FOR A.E.C. BY
GENERAL ELECTRIC

Schenectady, New York

PHYSICISTS—For opportunities, see our ad elsewhere in this section.

One Example of Internuclear Work



DESIGN AND DEVELOPMENT FOR THE FLUX TRAP CONCEPT OF AN ADVANCED ENGINEERING TEST REACTOR

• ANOTHER EXAMPLE - *Continuing consulting services to SENN*

Interesting jobs are available for reactor engineers who would enjoy participation in the growth of a small and independent company with excellent salaries and employee benefits

In particular . . . NUCLEAR ENGINEERS
REACTOR PHYSICISTS
REACTOR INSTRUMENTATION ENGINEERS
are needed

Call or write: TECHNICAL DIRECTOR

INTERNUCLEAR CO. PA 7-2668 **Clayton 5, Mo.**

GENERAL NUCLEAR ENGINEERING CORPORATION

has important contracts for
the design and development of Gas Cooled Reactors and Boiling Water Reactors and has an immediate need for

- **Reactor Physicists**
- **Mechanical Engineers**
- **Reactor Instrumentation Engineers**
- **Reactor Metallurgists**
- **Technical Report Writers**

Applicants must have engineering or scientific degrees and a minimum of two years experience in nuclear energy. Salaries will be commensurate with ability, training, and experience.

Send resumes to L. C. Furney
General Nuclear Engineering Corporation
Dunedin, Florida

ELECTRONICS ENGINEER
($20,000 PER YEAR)
Division of multiple plant manufacturing company seeking Electronics Engineer with advanced degrees for the micro wave-energy device field. Supervise 15 men highly specialized laboratory. Company client assumes all employment expense.
ESQUIRE PERSONNEL SERVICE, INC.
202 South State St. Chicago 4, Ill.

RADIATION PHYSICIST
Plant located in vacationland area. Experience desired in plasma physics, shock wave effects, atmospheric physics, etc. Degree from B.S. to Ph.D. Highly challenging position with high level contacts. Confidentially handled with no fee. Salary very interesting.
MONARCH PERSONNEL
28 E. JACKSON, CHICAGO 4, ILLINOIS

Wanted:

Editor for
NUCLEONICS
Engineer
with working experience in reactor technology
Send resume, salary requirements to
The Editor, NUCLEONICS
330 West 42nd Street
New York 36, New York

RESEARCH METALLURGIST

(Ph.D. or M.S.)

is needed to act as Project Leader on challenging programs concerning refractory metals and other reactor materials. Applicants should possess several years of related research and development experience although personal drive, enthusiasm and ambition are more important than specific technical experience. Our environment is midway between academic and industrial research and, insofar as practical, offers the opportunity to develop research programs of greatest appeal to your personal interests. Professional development is encouraged through publication of papers and participation in professional activities. Imaginative thinking is highly valued and the individual abilities of our dynamic staff are recognized and rewarded.

ARF is a mature, nationally known independent research organization with a staff of over 600 engineers and scientists contributing to a wide variety of military and industrial research programs. As a staff member you will receive a salary commensurate with your background and experience plus liberal benefits which include tuition-free graduate study, up to four weeks vacation, and a generous relocation allowance.

If you are an experienced research metallurgist and interested in this unusual opportunity for professional advancement, send a complete resume to:

A. J. Paneral
ARMOUR RESEARCH FOUNDATION
of Illinois Institute of Technology
Technology Center
Chicago 16, Ill.

RURAL AMERICA'S FIRST ATOMIC REACTOR PLANT

ELK RIVER, MINN.

WANTED
EXPERIENCED REACTOR OPERATION SUPERVISOR

Chief Reactor Operator to take complete charge of a 58 MW boiling water reactor plant operation. Must be able to supervise operators and assume responsibility for all technical problems associated with routine operation of the reactor. The construction of this plant is underway and will be ready for startup operation in the fall of 1960. Experience should be preferably with boiling water reactors. College graduate preferred but not essential if heavy on reactor experience. Prior to operation the man selected will assist in the preparation of operating manuals, procedures and become familiar with the overall plant design and construction.

The atomic plant is located on U. S. 169 and 10, 26 miles N. W. of Minneapolis and St. Paul where living conditions are excellent. The Land of 10,000 Lakes offers a real opportunity to the successful applicant.

If interested write
Rural Cooperative Power Association,
Elk River, Minnesota

stating experience, date available, starting salary expected and availability for interview.

NUMEC

Nuclear Materials and Equipment Corporation in the Pittsburgh area is engaged in a broad R & D effort on plutonium bearing fuel materials. Openings exist for:

REACTOR PHYSICISTS
MA or PhD. to develop criticality calculation procedures that take into account the nuclear behavior peculiar to the various plutonium isotopes.

REACTOR ENGINEERS
Familiar with existing codes to set up interim procedures for optimizing fuel cycles and performing fuel economics studies.

METALLURGISTS, CERAMICISTS
To plan and carry out experiments on plutonium and mixed oxide powders and compacts.

CHEMICAL ENGINEERS
To develop process lines for making plutonium fuel elements.

MECHANICAL ENGINEERS
To design and operate novel equipment or to modify existing apparatus for remote operation.

Please send a complete resume to:
Dept. P
Nuclear Materials & Equipment Corp.
Apollo, Pennsylvania

for
POSITIONS
in the
NUCLEAR
FIELD...

WRITE US FIRST!
Use Our Application
No Resume Required

Our national coverage and technical experience in the nuclear field offers the maximum opportunity to achieve your goals.

Confidential Handling
Employer Pays Fee

Write: Arthur L. Krasnow

ATOMIC PERSONNEL, INC.
1518 Walnut St. • Phila. 2, Pa. • PE 5-4908
An Employment Agency for the Nuclear Field

NUCLEAR PROCESS DEVELOPMENT

Excellent opportunity for chemist or chemical engineer with experience in uranium fuel material processing. The man we are looking for must have a minimum of three years' experience in the handling of uranium and its compounds, preferably with pilot plant or product development background.
Position is in process and product development of our rapidly expanding commercial Nuclear Fuel Department. Please send detailed resume to:

W. H. Swope, Jr.
Personnel Manager
SPENCER CHEMICAL COMPANY
Dwight Building, Kansas City 5, Missouri

Supervising Scientist

for

Nuclear Radiation Laboratory

of

REPUBLIC AVIATION

The highly capable man we seek for this vital assignment must presently occupy a responsible supervisory position in charge of a significant nuclear radiation facility. He must possess the ability to direct scientific personnel and technicians in scheduling, setting up and running complex nuclear experiments. A broad knowledge of hot cell and radiochemical laboratory operations; use of radioactive sources such as Cobalt 60, reactors, and accelerators; and modern counting techniques is a prerequisite.

A PhD in engineering or nuclear physics and 8 years or more experience is required. An understanding of experimental requirements for all the following areas (with considerable background in at least several) is required:

- ANP Shielding
- ANP Propulsion: Turbojet, Rocket, Ramjet, Electric
- Secondary Nuclear Auxiliary Power Devices for Satellites and Space Vehicles
- Radiochemistry Experiments
- Radioisotope Usage
- Nuclear Weapons Effects
- Radiation Environments in Space

Send resume to

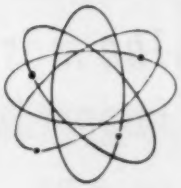
Mr. George R. Hickman

Technical Employment Manager

REPUBLIC AVIATION

Farmingdale, Long Island, New York

Needed in the field of ATOMIC ENERGY



As contract operator for the Atomic Energy Commission, the National Lead Company of Ohio utilizes the latest technical equipment and technology to produce uranium fuel elements for use in nuclear reactors.

• INSTRUMENT ENGINEER:

B.S. degree in mechanical or electrical engineering. Minimum of 5 years' experience in maintenance field including industrial instrumentation.

• METALLURGICAL ENGINEERS:

B.S. degree and metals industry experience in foundry or fabrication technology—heat treating—metallography—physical testing—metals process control. Positions may involve assisting, planning, executing development projects in uranium.

• CHEMICAL ENGINEER:

B.S. plus graduate degree or equivalent experience. For process development program aimed at more efficient production of nuclear fuels.

Please send resumé of education, experience and salary requirements to

EMPLOYMENT SUPERVISOR, Dept. J-101,

National Lead Company OF OHIO

P.O. Box 158, Cincinnati 39, Ohio

NUCLEAR ENGINEERS

Horizons are Unlimited for Intermediate Engineers and Recent Engineering Graduates.

Send resume to Personnel Department

NAVAL REACTORS DIVISION

COMBUSTION ENGINEERING, INC.

BOX 400, WINDSOR, CONN.

The most important rule at C. H. WHEELER

The emphasis is on engineering at C.H. Wheeler. Here you'll find an Engineering Department specially geared to the development of canned pumps, condensers, glandless valves, heat exchangers, pressure vessels, test loops and other products of similar scope.

Some of these engineers started working in the nuclear field 19 years ago. All are highly-skilled, imaginative and creative. Back of them is 71 years of engineering and manufacturing experience.

Isn't this the kind of organization you need to help you out? Ask about the engineering, development and manufacturing services now available to consultants, contractors and industry.

Serving Industry For Nearly Three-Quarters Of A Century

Atomic Products Division

C. H. Wheeler Mfg. Co.

19TH & LEHIGH AVENUE

Philadelphia 32, Pennsylvania

Atomic Products • Centrifugal, Axial and Mixed Flow Pumps • Steam Condensers • Vacuum Equipment
Marine Auxiliary Machinery

New Production/research instruments from **Gyra**

MULTIPURPOSE ELECTROMETERS FOR MEASUREMENT AND CONTROL

- Drift less than 2% full scale per week on 10^{-11} or greater currents
- Sensitivity: 10^{-12} amp full scale
- 10 mv recorder output
- Service tubes without removing instrument from rack
- Voltage regulation unnecessary; accepts full 50-60 cps

Series E-100 Electrometers are the result of six years of concentrated design activity to develop an instrument offering superior stability and accuracy in the low price range. Gyra Electrometers are characterized by the Bucknam circuit, which incorporates double regulation of the electrometer stage to achieve superior long-term drift.

GENERAL SPECIFICATIONS

Accuracy: within 2% full scale to 10^{-7} amp; 3% on all other ranges. Output noise level: less than 2% full scale on 10^{-11} amp or greater. Input drop: less than 6 mv. Zero check button allows zeroing without disturbing circuit (optional at $10.00 additional by adding suffix B to model numbers.) Power: 105-125 v, 50-60 cps, 30 watts consumed. Mechanical and electronic trips available (see table.) Slow or fast response circuits, 0.01 to 2 seconds, available (specify when ordering.) All prices F.O.B. LaGrange, Illinois.

E-105 Electrometer

MODEL	FULL SCALE RANGES	DIMENSIONS INCHES	TRIP MECHANISM	PRICE
E-100	10 decades to 10^{-13}	19x10x5¼	—	$325.00
E-102	10 decades to 10^{-13}	19x10x3½	—	325.00
E-105	10 decades to 10^{-13}	19x10x1¾	—	350.00
E-106	10 decades to 10^{-13}	19x10x3½	(M)	495.00
E-107	9 decades* to 10^{-13}	19x10x3½	(M)	520.00
E-108	9 decades* to 10^{-13}	19x10x5¼	(M)	520.00
E-109	10 decades to 10^{-13}	19x10x3½	(ER)	550.00
E-110	10 decades to 10^{-13}	19x10x5¼	(ER)	550.00
E-111	9 decades* to 10^{-13}	19x10x3½	(ER)	570.00
E-112	9 decades* to 10^{-13}	19x10x5¼	(ER)	570.00
E-113	9 decades* to 10^{-13}	19x10x5¼	—	350.00
E-114	9 decades* to 10^{-13}	19x10x3½	—	350.00

*Dual scale on these models permit reading 3 x 10^{-6} to 3 x 10^{-13} in eight decades. (M) mechanical trip, 0 to 100% of meter. (ER) electronic trip, for reactors, positive signal only.

Inquiries solicited for the design of related instrumentation. For complete literature; write:

Gyra ELECTRONICS CORPORATION

P. O. BOX 184 • LAGRANGE, ILL. • FLeetwood 4-4644

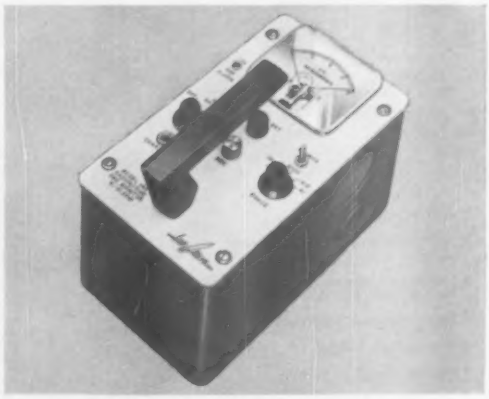
SALES REPRESENTATIVE: ROBT. M. LUNDGREN & CO. • P.O. BOX 201 • Batavia, Ill. TRemont 9-3486

NEW PORTABLE RADIOACTIVE GAS MONITOR

SENSITIVE TO:

TRITIUM (H^3)
RADON (Rn^{222})
KRYPTON 85 (Kr^{85})
CARBON 14 (C^{14})

Completely self-contained, the Land-Air Model 149 Radioactive Gas Monitor features audio alarm which may be set at any desirable threshold to furnish instant warning if radioactive gas concentration exceeds your predetermined limit. Weighing only 12 pounds, the model 149 requires no external power supply. It may be readily located in areas subject to contamination from Nuclear Reactors, Accelerators, Carbon 14 research, or Tracer research. A quickly attached flexible hose and probe increases the adaptability of this monitor to Health Physics Instrumentation, Area Monitoring, Air Pollution, and Leak Detection.



SPECIFICATIONS

SENSITIVITY—0-10^2, 0-10^3, 0-10^4, 0-10^5 Microcuries Per Hour
BATTERY LIFE—Electronics 500 Hours, Blower 15 Hours (rechargeable)
SOURCE—Push Button Operated, Less than 1 Microcurie Radium
AIRFLOW—2.5 C.F.M. Depending on Filters (Built-in Blower)
ELECTROSTATIC PRECIPITATOR—1 Kilo-volt Per Centimeter Gradient
ALARM—Preset at any desired Threshold
DESSICANT—Dries Electrometer Compartment
INTERLOCK—Removes High Voltage when Top Cover is removed.

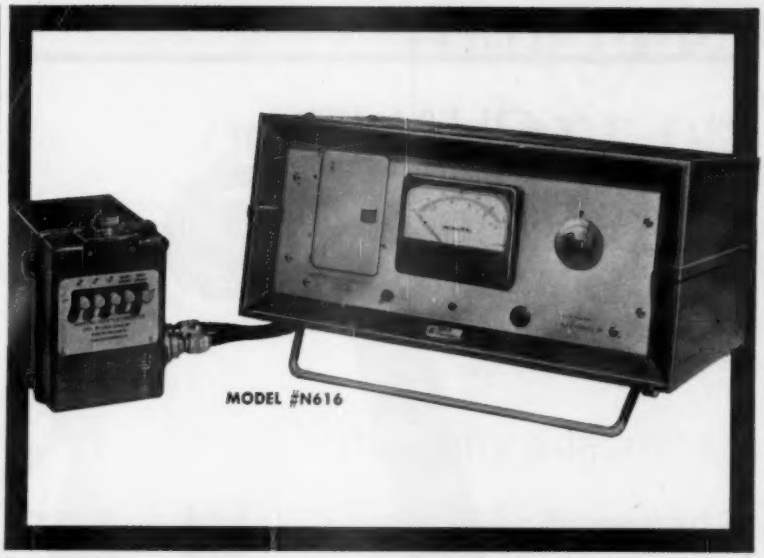
Land-Air INC. *For complete information write to:*

INSTRUMENTS AND ELECTRONIC DIVISION
7444 W. Wilson Avenue, Chicago 31, Ill.

INDEX TO ADVERTISERS

FEBRUARY 1960

Alco Products, Inc. 49
American Smelting and Refining Company 33
American Tradair Corp., Ekco Electronics Ltd. 133
Anton Electronic Laboratories, Inc. . 118
Argonne National Laboratory, Idaho Division 46, 47
Atomic Energy of Canada Limited . . 44
Atomics International, A Division of North American Aviation, Inc. 48, 94 95
Automatic Switch Co. 39
Babcock & Wilcox Company, Boiler Division 1
Bendix Aviation Corporation, Cincinnati Division 122
Blickman, Inc., S. 91
Bristol Company, The 2
Bristol Siddeley Engines Limited . . . 34
Budd Company, Spaceatomics Div. . . 31
Cambridge Instrument Company, Inc. 104
Carlson Inc., G. O. 35
Central Research Laboratories, Inc. . 81
Central Scientific Co. 91
Consultants Bureau, Inc. 89
Cornell-Dubilier Electric Corporation 116
Corning Glass Works 87
Crawford Fitting Company 113
Crystals Division Isotopes, Inc. 108
Davison Chemical Division, W. R. Grace & Co. 11
Delta Chemical Works, Inc. 106
E.M.I. Electronics Limited 107
Eberline Instrument Corporation . . . 115
Engineers Joint Council 51
Gaertner Scientific Corp. 92
General American Transportation Corporation 38
General Mills—Nuclear Equipment Dept. 30
General Motors Research Laboratories 41
Great Lakes Carbon Corporation . . 9
Hamner Electronics Co. Inc. . . 2nd Cover
High Voltage Engineering Corporation 99
Hughes Aircraft Company 10
Illinois Water Treatment Co. 95
Isomet Corporation 91
Gyra Electronics Corporation 132
Kaman Nuclear, A Division of the Kaman Aircraft Corp. 50
Kaiser Engineers . . . . . 3rd Cover
Land-Air, Inc. 132
Landsverk Electrometer Co. 8
Leeds & Northrup Co. 15
Linde Company, Division of Union Carbide Corporation 103
Los Alamos Scientific Laboratory . . . 7
M&C Nuclear, Inc. A Subsidiary of Texas Instruments Incorporated . . 97
Mallinckrodt Nuclear Corporation . . 83
Marman Division Aeroquip Corp. . . 119
Martin Company, The 5
Minneapolis-Honeywell 12, 13, 40
National Carbon Company, Division of Union Carbide Corp. . . . 4th Cover
National Lead Company 52



NEW . . . . . THE EKCO N616 VIBRATING REED ELECTROMETER

Unsurpassed performance and flexibility at low cost. Proudly offered as successor to the widely used and well known EKCO N572 Electrometer.

The name Ekco Electronics, Ltd. signifies more than world-wide representation and acceptance on six continents. Whether it be instruments for precise radiation measurements, unique laboratory research, reactor monitoring, public health and plant safety, or industrial gaging through isotopes, Ekco Electronics, Ltd. on the nameplate of an instrument represents the acme of excellence in design, performance, dependability and long-lasting value. An impressive list of companies and institutions throughout the world use Ekco equipment.

The above instrument is one of a large and complete range of EKCO instruments described more completely in the EKCO catalogues available upon request. We cordially solicit your inquiry. Write today for name of franchised EKCO representative nearest you.

NOW FULLY PROVEN

the EKCO low-cost Scintillation System for Tritium and Carbon 14 counting.

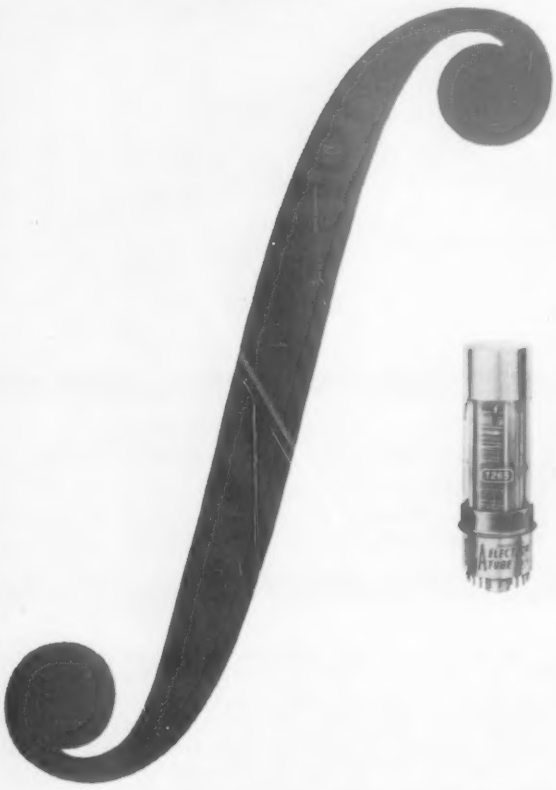
The EKCO Scintillation Counter has been thoroughly evaluated and proved in actual use. It is accepted as the best dollar value on the market . . . convincing proof that superb instrumentation need not be expensive.

AVAILABLE FOR IMMEDIATE DELIVERY

EKCO ELECTRONICS, LTD.

In U. S. A., address all inquiries to:
American Tradair Corporation, 34-01 30th Street,
Long Island City 6, New York
ELSEWHERE: Ekco Electronics Ltd., Southend, England

QUALITY...



an in-te-gral part

OF RCA MULTIPLIER PHOTOTUBES

RCA offers a wide range of multiplier phototubes. For example, there are types featuring high cathode sensitivity, types with very low noise, and types with extremely fast time resolution. In addition, types such as the RCA-7265 combine these features plus other desirable characteristics like low equivalent anode dark current input and exceptionally high current amplification.

RCA Multiplier Phototubes are performance-proved in every applicable field involving extremely low-level light detection including astrophysics and nuclear radiation instrumentation. For prompt service on any RCA Multiplier Phototube,

CALL YOUR RCA INDUSTRIAL TUBE DISTRIBUTOR

RADIO CORPORATION OF AMERICA

Electron Tube Division — Harrison, New Jersey

Nuclear Development Corporation of America 16
Nuclear Enterprises Ltd. 121
Nuclear Measurements Corporation 6, 93
Nuclear-Ohio, Inc. 122
Pechiney Division Applications Atomiques 14
Penberthy Instrument Co. 125
Philips' Gloeilampenfabrieken N. V. 120
Picker X-Ray Corp. 79, 96
Pioneer Service & Engineering Co. . . 32
Radiation Counter Laboratories, Inc. 29
Radiation Instrument Development Laboratory, Inc. 77
Radio Corporation of America 134
Rawson Electrical Instrument Company 108
Searchlight Section 127–131
Southern Lead Rolling Company . . 106
Standard Pressed Steel Nuclear Components Division 42
Stokes Corporation, F. J. 109
Stromberg-Carlson, A Division of General Dynamics 37
Superior Tube Company 45
Technical Associates 117
Texas Nuclear Corporation . . . 115, 125
Thermal American Fused Quartz Co., Inc. 105
United States Radium Corp. 111
Van Nostrand Company, Inc., D. . . . 124
Varian Associates 123
Victoreen Instrument Company . . 84, 85
Westinghouse Atomic Power Dept. . 110
Westinghouse Electric Corp. Bettis Atomic Power Laboratory 36
Wheeler Mfg. Co., C. H. 132
Where To Buy 125
Wolverine Tube Division of Calumet & Hecla, Inc. 43

●

PROFESSIONAL SERVICES . . 125

CLASSIFIED ADVERTISING
F. J. Eberle, Business Mgr.

EMPLOYMENT OPPORTUNITIES 126–131
Advanced Technology Laboratories, Div. of American-Standard 126
Alco Products Inc. 128
Armour Research Foundation of Illinois, Institute of Technology 128–130
Atomic Personnel, Inc. 130
Combustion Engineering Inc., Naval Reactor Division 131
Esquire Personnel 129
General Electric Company . 127, 129
General Nuclear Engineering Corp. 129
Gibbs & Hill, Inc. 128
Internuclear Company 129
Monarch Personnel 129
National Lead Company of Ohio 131
Nuclear Materials and Equipment Corp. 130
Republic Aviation 131
Rural Cooperative Power Assoc. . 130
Spencer Chemical Company . . . 130

This index is published as a service. Every care is taken to make it accurate, but NUCLEONICS assumes no responsibility for errors or omissions.

Your new power plant or expansion idea

Location correct?

Capacity adequate?

Readily financed?

Timely?

Kaiser Engineers designs and builds a wide variety of power plants and nuclear facilities.

Among KE's most valued services are sound, searching economic analyses, feasibility studies and site evaluations. In a word—*Pre-Engineering*—impartial, outside analysis which helps you decide whether to proceed with, defer or modify the project.

Kaiser Engineers offers you cost-saving, time-saving, one-company service from concept through start-up.

KAISER ENGINEERS

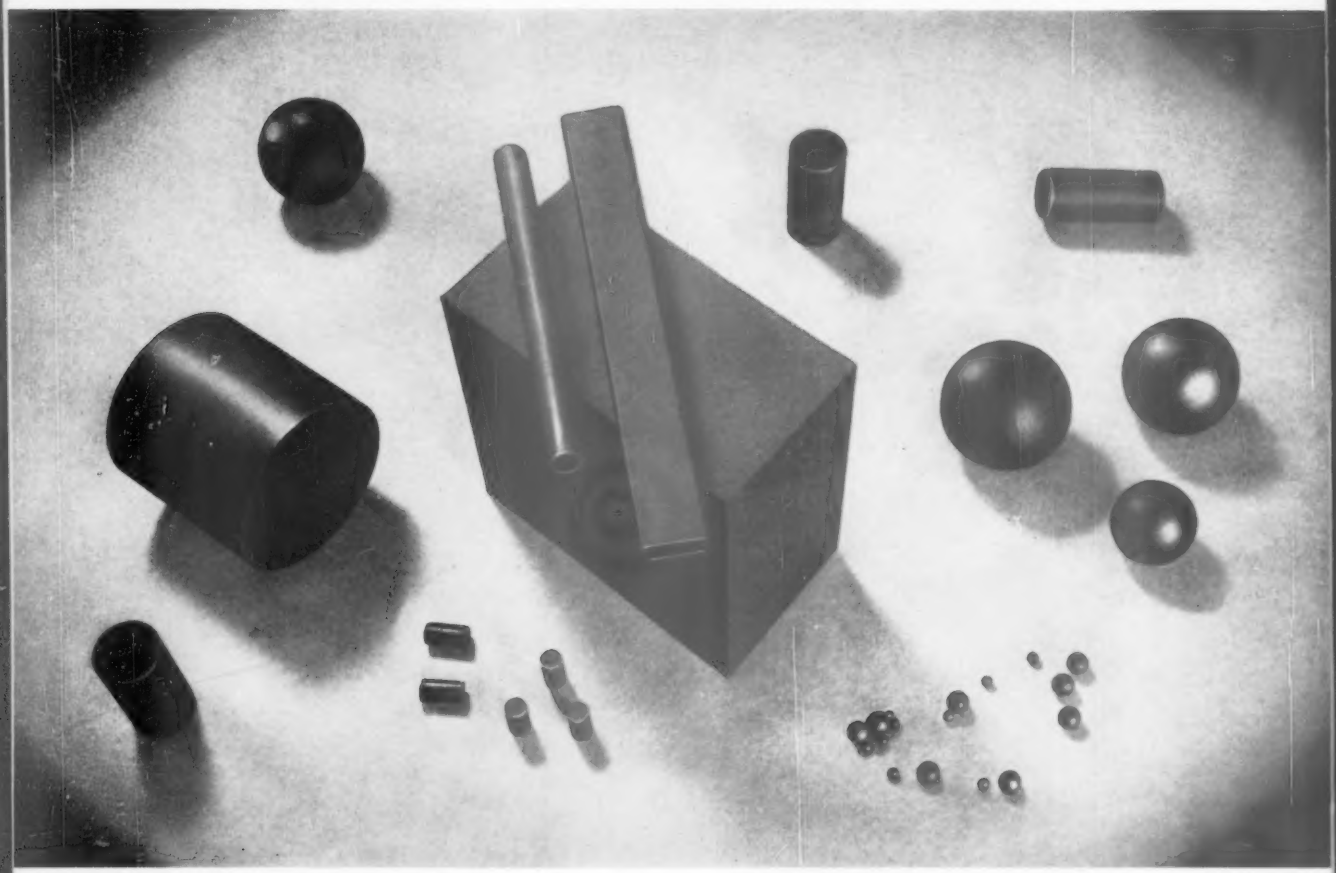
Division of Henry J. Kaiser Company
Oakland 12, California
Pittsburgh, Washington, D. C., Chicago, New York

• KE projects include work in Ghana, Japan, Puerto Rico, Vietnam, as well as the United States. They encompass such diverse assignments as nuclear fuel analysis, a nuclear research center, plutonium production reactor, steam-electric power station and a hydro-electric plant.

5489-P

NATIONAL NUCLEAR GRAPHITE...

TRADE MARK



Some typical "National" graphite nuclear fuel element concepts.

Graphite's unique properties conform to the many requirements for high temperature fuel elements

- High temperature strength.
- High thermal conductivity.
- Resistance to thermal shock.
- Dimensional stability.
- No practical melting point — safety.
- Low neutron absorption — neutron economy.
- Neutron moderation.
- Resistance to radiation damage.
- Flexibility of design.
- Simplified reprocessing of spent elements.

FUEL ELEMENT CONCEPTS FOR HIGH TEMPERATURE REACTORS

Today, there is intense interest in obtaining nuclear heat at temperatures above 800-900°C. To accomplish these high temperatures, industry must develop a reliable fuel element. National Carbon Company has undertaken an extensive research and development program to help meet this need. Illustrated above are a number of graphite matrix nuclear fuel element conceptual designs for high temperature reactors.

Dispersions of fissionable and fertile materials — uranium and thorium oxides, or carbides — in a graphite matrix will permit operation of reactors at higher temperatures, higher specific power, high burn-up, low fuel fabrication cost and excellent neutron economy. Spent fuel processing may be considerably simplified when graphite base fuel materials are used.

National Carbon Company is presently conducting extensive research to further develop impervious graphite and effective impervious coatings for retaining fission products and preventing oxidation. Remember . . . no other material today has so many useful nuclear properties as does "National" Nuclear Graphite.

Write today for 8-Page Brochure "'National' Nuclear Graphite"

UNION CARBIDE

"National" and "Union Carbide" are registered trade-marks of Union Carbide Corporation

NATIONAL CARBON COMPANY • **Division of Union Carbide Corporation** • ***30 East 42nd Street, New York 17, N.Y.***

OFFICES: Birmingham, Chicago, Houston, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco • **CANADA:** Union Carbide Canada Limited, Toronto